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A STATUS REPORT

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LIMNOLOGICAL STUDIES OF FLATHEAD LAKE MONTANA: A Status Report

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Flathead Lake, a dimictic oligotrophic lake located in western Montana, has been the subject of several investigations beginning with Forbes' study of aquatic invertebrates in the lake in 1893. Young in 1935 presented the results of four years of data collecting on the chemistry and biology of the lake. During the last ten years (1964-1974) a number of limnological studies have been conducted dealing with the physical, chemical, and biological characteristics of the lake. The objectives of these studies have been to determine the standing crop of phytoplankton and zooplankton during all seasons of the year, to observe the succession, distribution and diversity of planktonic forms, to determine the role of chemical nutrients in relationship to phytoplankton productivity, and to study fish population trends, life histories and seasonal fish distribution of the Flathead Lake system.

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LIMNOLOGICAL STUDIES OF FLATHEAD LAKE MONTANA: A STATUS REPORT

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ABSTRACT

Flathead Lake, a dimictic oligotrophic lake located in western Montana has been the subject of several investigations beginning with Forbes' study of aquatic invertebrates in the lake in 1893. Young in 1935 presented the results of four years of data collecting on the chemistry and biology of the lake. During the last ten years (1964-1974) a number of limnological studies have been conducted dealing with the physical, chemical, and biological characteristics of the lake. The objectives of these studies have been to determine the standing crop of phytoplankton and zooplankton during all seasons of the year, to observe the succession, distribution and diversity of planktonic forms, to determine the role of chemical nutrients in relationship to phytoplankton productivity, and to study fish population trends, life histories and seasonal fish distribution of the Flathead Lake system.

The composition of the algal flora of Flathead Lake in number of species so far reported is Chlorophyta 102 species (17.5%); Cyanophyta 40 species (7%); Chrysophyceae 12 species (2.1%); Bacillariophyceae 399 species and varieties (69.8%); Pyrrhophyta 13 species (2.0%); Xanthophyceae 4 species; Euglenophyta 1 species; and Cryptophyta 2 species. The Chrysophyta as a phylum (Diatoms and Chrysophyceae) thus constitutes by far the dominant floral group. In this respect the lake shows an oligotrophic character remindful of the oligotrophic flora in arctic lakes.

Nitrates and phosphates are relatively low as might be expected. Levels of these critical nutrients that have been reported are high enough to occasionally support plankton blooms. That extensive blooms do not occur is possibly due to oligotrophic features such as low temperatures and low concentrations of organic acids and vitamins.

The more common forms of zooplankton found in the lake, Daphnia spp., Kellicottia longispina, Keratella cochlearis, Cyclops bicuspidatus thomasi, and Diaptomus ashlandi, compose a community similar to that described by Sheffer and Robinson (1949) for Lake Washington. The distribution of Daphnia spp. in the lake has been of particular interest because their temporal and spatial distributions seem to be influenced primarily by temperature.

A total of 8,912 fish were collected in 163 net sets during the fish sampling program on the lake from November 1967 through December 1971. Fifteen major fish species were collected with the lake whitefish, kokanee salmon, Dolly Varden, and lake trout being the most common game species in that order of abundance.

This report was submitted in fulfillment of Training Grant No. 1-F1-WP26, 212-1-4, by the University of Montana Biological Station, under the sponsorship of the Federal Water Quality Administration and Environmental Protection Agency. Work was completed as of June 1973.

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This project was directed by the following three principal investigators: Arden R. Gaufin, Department of Biology, University of Utah and Montana University Biological Station; Gerald W. Prescott, Resident Biologist, University of Montana Biological Station, Bigfork, Montana, and John F. Tibbs, Director, University of Montana Biological Station, Bigfork, Montana.

Each of the principal investigators also participated in several aspects of the research conducted during the course of the project.

The work on the distribution, ecology, and production of phytoplankton in the lake was conducted principally by Fatimah Moghadam, Garth R. Morgan, and Thomas Ivory, graduate students at the University of Utah and Montana Biological Station. This work served as a basis for Ph.D. theses presented to the University of Utah, Salt Lake City, Utah. Without their untiring efforts the research conducted on the phytoplankton could not have been completed.

Special thanks are extended to Dr. William Vinyard, Professor of Botany, California State University at Humboldt, Arcata, California, and to Dr. Ruth Patrick of the Academy of Natural Sciences of Philadelphia, Pennsylvania, for their help in the identification of diatoms from the lake.

David S. Potter, a graduate student at the University of Montana, has conducted a study of the zooplankton of the lake during the last three years and is to be credited for the section of the report dealing with the systematics and ecology of zooplankton in the lake.

The section of the report entitled the Fish Population of Flathead Lake was contributed by Delano A. Hanzel of the Montana Fish and Game Department and represents the work of him and his associates over a period of ten years (1962-72). The principal investigators especially acknowledge Mr. Hansel's contribution and wish to thank the Montana Fish and Game Department for their help and cooperation.

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SECTION I

CONCLUSIONS

Flathead Lake is of such a quality that it is presently classified as an A-open D_1 lake by the Montana Water Pollution Control Authority. Under the present classification water may be used for drinking, culinary and food processing purposes for use after simple disinfection treatment and removal of natural impurities. Coliform bacteria concentrations obtained near the shores by Bauer[1] and Hern[2] often exceeded the state standard for the lake (50 coliforms per 100 ml). Samples taken away from the shoreline were consistently low, and no fecal coliforms were found.

Various studies conducted on the lake have clearly demonstrated that it is a cold dimictic lake exhibiting submerged depression individuality. While much of the lake stratifies thermally, there are several extensive shallow bays such as Polson Bay which do not do so.

The algal flora of Flathead Lake, both quantitatively and qualitatively, reflects its limnologic and hydrographic uniqueness. Very low turbidity, a strong channel current from the Flathead River, a distinctly fluctuating water level, and a relatively deep basin which contributes to and maintains low temperatures all contribute to the oligotrophic characteristics of the lake.

The algal flora can be classified as a Diatom-Cyanophyte moderately hardwater type. However, the cyanophyte element is not only lower in number of taxa, but is also more weakly developed than lakes which fall within such a classification. The diatoms comprise the dominant flora at all times of the year with 399 species and varieties in 42 genera having been reported.

Nitrates and ortho-phosphates are relatively low as might be expected. However, the development of blue-green algal blooms during recent years in shallower bays as Yellow Bay and Hell Roaring Bay indicate that such sections of the lake are gradually undergoing eutrophication.

The Flathead Lake fishery is dependent on the natural reproduction in the lake and recruitment from the tributary system above the lake. A total of 8,912 fish were collected in 163 gill net sets during a sampling program conducted by the Montana Fish and Game Department from November 1967 through December 1970. The dominant game fish taken were cutthroat trout, Dolly Varden, kokanee, lake trout, mountain whitefish, and lake whitefish.

The future of the Flathead Lake fishery is dependent on the natural reproduction in the waters of this complex system. The quality of the fishery available will be dependent on the quality of the aquatic habitat. Changes caused by natural variations in the environment, as

well as the results of man's activities in water development projects, housing projects, lumbering or a combination of many factors will be reflected in the fish populations of this drainage system.

SECTION II

INTRODUCTION

FLATHEAD LAKE

Flathead Lake is located in the northern portion of a large glacial valley in Northwestern Montana, near Glacier National Park. The lake is a remnant of a much larger lake which occupied the area during Tertiary times.

During the late Wisconsin stage, approximately 10,000 years ago, a glacier filled Flathead Valley. The retreat of the glacier deposited a terminal moraine near Polson, Montana, and left the Flathead Valley partially filled with sand, clay, and silt. This moraine at present forms the southern boundary of Flathead Lake (Ross,3).

Flathead Lake is the largest natural body of fresh water west of the Mississippi River. It is 56.4 kilometers by 25.8 kilometers in its extremes of length and width, and it has a maximum depth of 112 meters. The lake has a shoreline of 185 kilometers more than half of which is composed of rock (quartzitic argillite, quartzite, and carbonate) and gravel which extends lakeward to a depth of approximately 30 meters (Moghadam,4). At the extreme northern and southern portions of the lake the rock and gravel bottom gives way to sand or an ooze consisting of sand, clay, and organic detritus. Nearly half of the shoreline is composed of rocky cliffs, and the remainder is sandy or rocky beach.

Flathead Lake is bounded on the east shore by the Mission Mountains whose steep slopes arise almost at the water's edge. On the west shore the mountains are lower and are intermittently cut by valleys. The steepness of much of the drainage area and its close proximity to the lake greatly limits the amount of drainage into the lake.

DRAINAGE AREA

The drainage area of Flathead Lake at Polson encompasses approximately 7,010 square miles in Montana and Canada. The North Fork of the Flathead River at the international border has a drainage area of about 450 square miles in Canada, with an additional 175 square miles of drainage in Canada that flows into tributaries that enter the North Fork below the border. Of approximately 6,375 square miles of the drainage in Montana, 4,550 are in Flathead County and 850 square miles are in Lake County. Powell, Missoula, Lincoln and Lewis and Clark Counties contain about 425, 410, 90, and 65 square miles of the Flathead drainage, respectively (Fig. 1). All of Glacier National Park west of the divide, or 875 square miles, and most of Flathead National Forest's 3,680 square miles are located in the drainage. Three major rivers, the South, North, and Middle Forks of the Flathead River, join to form the main stream at

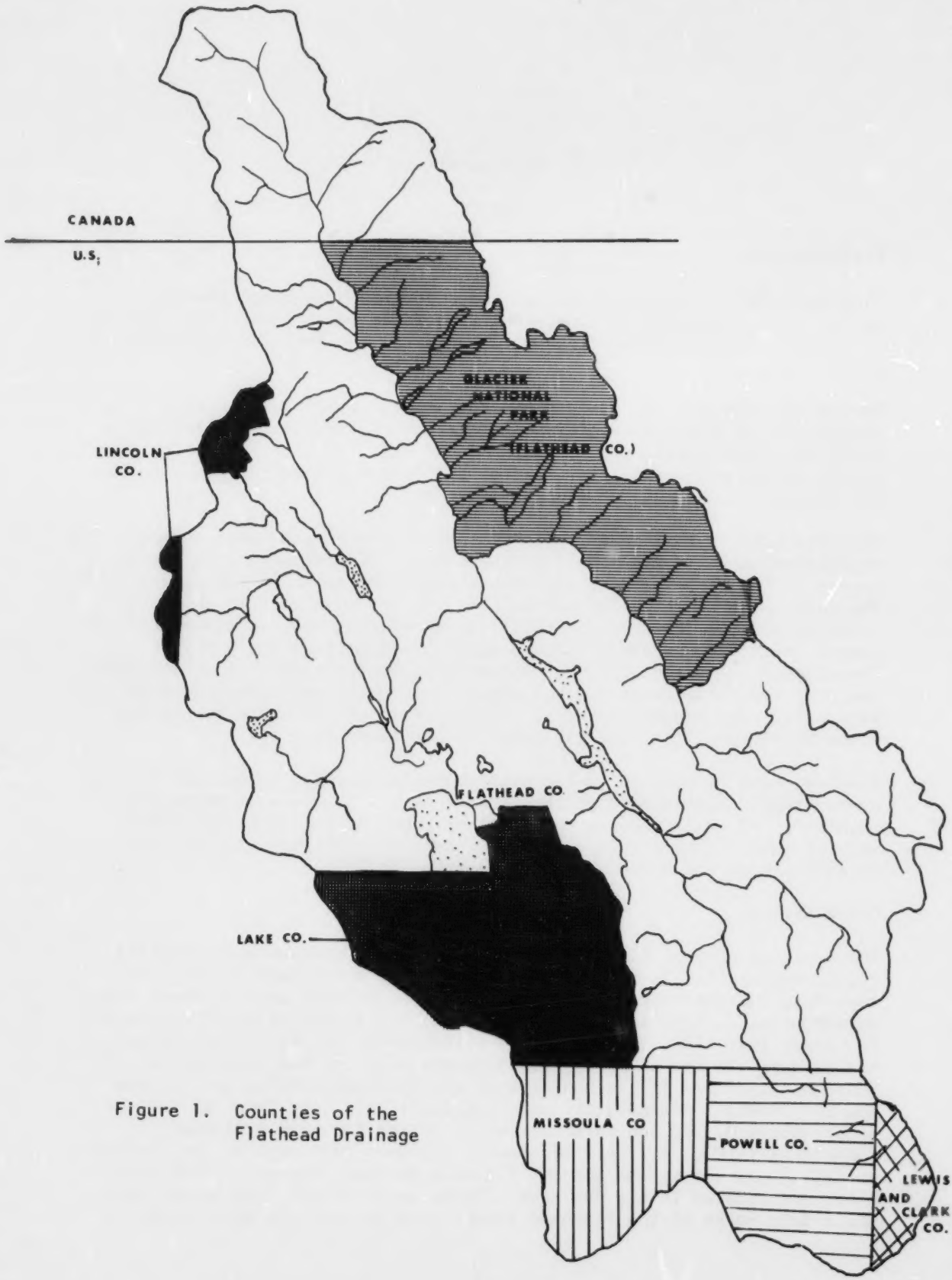

Figure 1. Counties of the Flathead Drainage

Hungry Horse, Montana. The Whitefish and Stillwater Rivers merge and empty into the Flathead River below Kalispell (Fig. 2).

An average of 8,405,000 acre feet of water flow through the gauging station near Polson yearly (11,610 cfs average). The average flow of the Flathead River below Kalispell before it empties into the lake is gauged with the flow averaging between 9,500 and 11,000 cfs. A major tributary, the Swan River, near Bigfork discharges an average of 1,127 cfs to Flathead Lake.

The largest tributary of the Upper Flathead River is the South Fork, which discharges an average of 3,523 cfs as modifed by Hungry Horse Dam. Next largest is the North Fork, discharging an average of about 3,000 cfs over the year. The Middle Fork discharges about 2,920 cfs average at the junction with the North Fork, forming the Flathead River Mainstem. The Stillwater and Whitefish Rivers discharge estimated averages of 350 cfs and 200 cfs respectively as they empty into the Flathead River.

EFFECTS OF GLACIATION

During the last great glacial advance, the Flathead Glacier, in its movement down the Rocky Mountain Trench, deposited not only the "Polson Moraine" at the south end of Flathead Lake but also various moraines in the Big Arm embayment. Near the middle of the lake, the ice moving southward split into two parts. One lobe continued south into Polson Bay. The other turned to the west and moved into the Big Arm embayment. The Big Arm ice split again into three smaller lobes; these, in turn, pushed into the Dayton, Big Draw, and Big Arm Valleys. These three smaller lobes deposited terminal moraines in each valley and these moraines are believed to be of the same age as the Polson Moraine.

Throughout the glacial period, glacial till accumulated in large volumes and buried much of the preglacial topography. These accumulations have resulted in many unusual land forms. As the ice released its load of till, great amounts of meltwater carved many features of unique shape into the local landscape. During the ice retreat several small preglacial lakes evolved, existed for a short time, and then drained as their ice dams melted. The present topography has had little modification since the glacial period. Many of the land forms found today still exhibit large volumes of glacial till and show the scars of fluvial erosion that resulted from the ice age.

HISTORY OF THE REGION

White settlement of the region around Flathead Lake occurred relatively late in the 19th century. Prior to the 1820's, the land was wilderness and belonged to Indians of the Salish Tribal Nation. The rate of settlement was slow but steady and was enhanced by the coming of the Great Northern Railroad in 1891. Lumber was, and remains, a principal industry of the area. The Stillwater, Whitefish, Flathead and Swan

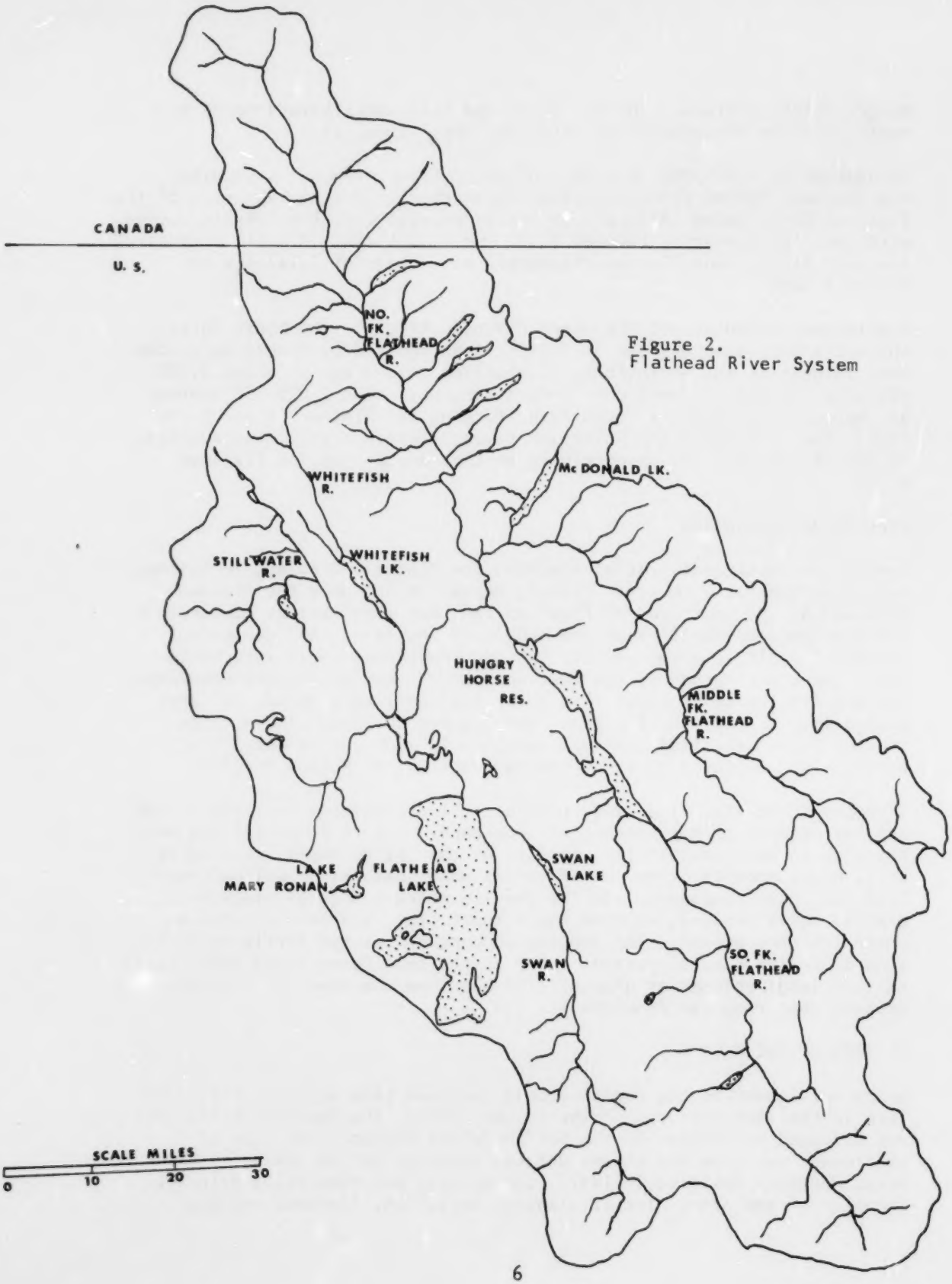

Figure 2.
Flathead River System

Rivers served as transport systems for the earliest lumber center at Somers, located on the northwest shore of Flathead Lake.

Flathead Lake served as a transport system from Polson to points north until a road (now highway 93) was built along the west side of the lake. Steamboats carried passengers and cargo to points along the lake and upper Flathead River. As a result, almost all virgin timber around the lake was cut to fuel these boats. The land now occupied by the University of Montana Biological Station represents the largest tract of relatively pristine forest along the lake.

The Flathead River system remained largely unmodified until the construction of Kerr Dam below Polson in 1938. The dam regulates the upper ten feet of Flathead Lake and has a capacity of 1,219,000 acre-feet (Montana Water Resources Board,[5]).

The Flathead drainage system was significantly modified by the Hungry Horse Reservoir. This dam began operation in 1953 on the South Fork of the Flathead River; the dam has a capacity of 3,468,000 acre-feet. The dam regulates much of the spring runoff on the South Fork, reducing the flow of the Flathead River during this period. Conversely, the dam discharges water during other periods of the year, correspondingly increasing the volume of the Flathead River.

INDUSTRIES AND MUNICIPALITIES

At present there are very few industries located on the tributaries of Flathead Lake and its surrounding shoreline areas. Anaconda Aluminum Company, located on the Flathead River at Columbia Falls, Montana, is the largest industry utilizing the river's water. The effluents from this industry are ponded or placed in dry wells on the company's property. Wood-product industries have used the main rivers and tributaries since the turn of the century. Agricultural practices are conducted throughout the lower valley areas of the two main tributaries. This includes practices such as grazing and watering of livestock, irrigation and runoff back into the streams.

The permanent population of the communities surrounding the immediate area of Flathead Lake is estimated at 7,000. Approximately 90 per cent of the population is served by municipal sewage treatment. The population of the Flathead Lake area is estimated to increase in summer to three times the permanent population. Summer residents reside in summer homes, trailers, campgrounds, motels and lodges. Most of these facilities use septic tank systems for sewage treatment. The population along the rivers studied consists of scattered homes plus three communities totaling 16,000 people. Kalispell with a population of over 10,000 is served by primary sewage treatment with post-chlorination but no retention time and discharges into Ashley Creek which eventually enters the Flathead River. Columbia Falls with a population of 2,132 has an aerated lagoon and Whitefish with 3,936 people uses a sewage lagoon system. Bigfork, population 500, is located on the Swan River at its point of

entry into the lake. This community utilizes secondary sewage treatment with chlorination but no retention time for disinfection. The sewage effluent of Bigfork enters directly into Bigfork Bay.

WATER QUALITY CLASSIFICATION OF LAKE

Flathead Lake is presently classified as an A-open D_1 lake by the Montana Water Pollution Control Authority. Under the present classification water may be used for drinking, culinary and food processing purposes suitable for use after simple disinfection treatment and removal of natural impurities. The water quality must also be maintained suitable for swimming and recreation.

The Flathead River above the lake is presently classified by the Montana State Water Pollution Control as B-D_1. This classification is strict enough to maintain the water for swimming, boating, growth and propagation of salmonid fish and other associated aquatic life, such as waterfowl and furbearers.

On October 5, 1967, the state of Montana adopted the following water quality criteria for Flathead Lake (Brink,[6]):

> "Concentrations of chemical constituents shall comform with the 1962 U.S. Public Health Service drinking water standards. Induced variation within these standards shall be limited to an increase of not more than ten per cent of the concentration present in the receiving water. The pH should be in the range of 6.5 - 8.5. Turbidity should be none. No evidence of matter other than that naturally occurring should be found, except real color shall not be increased more than two units above that naturally occurring.
>
> "Organisms of the coliform group by the most probable number (MPN) or equivalent membrane filter methods, during any consecutive 30-day period and using a representative number of samples, shall: average less than 50/100 milliliters (ml) when demonstrated by sanitary survey to be a result of domestic sewage."

With these stringent classifications of Flathead Lake and Flathead River, guidelines for controlling polluted effluents entering the lake are necessary.

CLIMATOLOGY

Monthly temperatures and precipitation for various stations in the drainage have been recorded for over fifty years at some locations. Precipitation records for Kalispell were initiated in 1897.

Mountain ranges are responsible for varying local climatological differences. The western side of the lake is in a rain shadow and receives less rainfall than the comparable altitudes on the east side of the lake.

The growing season varies from about 150 days at Kalispell to an estimated 30 days in the high mountainous areas.

Flathead Lake can be shown to modify local weather conditions somewhat, especially on the east side of the lake. Bigfork, Montana has the warmest annual temperatures and is cooler in the summer and warmer in the winter than other stations in the drainage. Weather modification by the lake, then, is responsible for the ability of the east side to support a local cherry orchard industry.

A summary of monthly mean values for temperature and precipitation is as follows:

Table 1. MEAN TEMPERATURE VALUES
(°F)

Location	Years on record	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann
Bigfork	21	26.2	29.8	35.2	45.2	53.5	59.1	61.5	65.9	57.1	47.0	35.3	31.0	46.1
Hungry Horse Dam	13	19.5	24.7	29.9	40.8	51.1	57.6	65.0	63.1	54.3	43.1	31.4	26.2	42.2
Kalispell	38	21.4	25.2	33.1	43.7	52.0	58.4	68.4	63.3	54.0	43.9	32.2	24.9	43.2
Polson Airport	47	24.1	27.7	33.2	44.7	52.7	59.9	67.5	65.8	56.2	46.1	34.7	28.6	45.1
West Glacier	46	20.8	24.6	31.7	41.8	50.5	57.0	64.5	62.5	53.2	42.9	30.9	24.3	42.1

Table 2. TOTAL PRECIPITATION
(inches)

Location	Years on record	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann
Bigfork	22	1.86	1.42	1.15	1.75	2.46	3.18	1.28	1.31	1.58	1.91	2.09	1.92	21.91
Hungry Horse Dam	13	3.65	2.71	1.93	2.02	2.49	2.94	1.58	2.05	2.13	3.33	3.29	3.02	31.14
Kalispell	65	1.51	1.12	0.92	0.87	1.51	2.05	1.13	1.00	1.17	1.08	1.36	1.42	15.14
	13	1.28	1.14	0.81	1.17	1.71	2.02	1.26	1.52	0.87	1.18	1.40	1.31	15.67
	52	1.57	1.11	0.95	0.80	1.46	2.06	1.10	0.87	1.24	1.06	1.35	1.45	15.02
Polson Airport	49	1.11	0.93	0.94	1.17	1.74	2.24	1.02	0.94	1.32	1.23	1.26	1.24	15.14
Kerr Dam	30	1.07	0.91	0.78	1.23	2.03	2.44	0.99	1.08	1.35	1.20	1.28	1.18	15.54
West Glacier	45	3.10	2.34	1.74	1.73	2.20	2.83	1.44	1.39	2.02	2.64	2.91	3.24	27.58
Whitefish NW	21	2.13	1.80	1.34	1.58	2.29	2.88	1.39	1.46	1.46	1.74	2.19	1.97	22.23

SECTION III

REVIEW OF WATER QUALITY STUDIES

Flathead Lake has been the subject of several investigations beginning with Forbes' study of aquatic invertebrates in the lake in 1893,[7]. Elrod,[8] discussed the geology and topography of the lake in his study of the zooplankton. "The Life of Flathead Lake" by Young[9] presented the results of four years of data collecting on the chemistry and biology of the lake. The data he collected constitute a very comprehensive basis for interpretation of changes which have occurred in the lake during the last half century.

Five papers have been published on the microbiology of Flathead Lake. Graham and Young,[10] studied bacteria of the lake and concluded that the fewest bacteria occurred on the surface and gradually increased toward the bottom. He found a heterogenous group of bacteria in the lake. Potter and Baker,[11,12] studied the chemistry and microbiology of Flathead Lake including the bacteria and fungi. Ninety-eight species of fungi were identified and the dominant types of bacteria were reported as Gram negative rods. Bauer,[1] investigated the occurrence of bacteria of the coliform group in the lake and Hern,[2] studied the relations of enteric bacteria to the water quality of the lake. Bauer found that coliform bacteria concentrations obtained near the shores often exceed the state standard for the lake (50 coliforms per 100 ml). Samples taken away from the shoreline were consistently low, and no fecal coliforms were found. "Septic tank seepage into the lake was shown to be capable of producing total coliform populations greatly exceeding the state standard." Hern's conclusions were very similar to those stated by Bauer. Data on coliform bacteria also have been obtained from 1966 to the present by the Lake County Sanitarian personnel (Robertson, unpublished data). These data also indicated high coliform concentrations near the shores, with late August, early September being the period of highest contamination. Intensified studies of the phytoplankton, zooplankton, fisheries and chemical and physical characteristics of Flathead Lake have been conducted by a number of individuals and agencies since 1966 and have produced an abundance of data. Bjork,[13] studied the zooplankton of the lake and reported 25 species of crustaceans and rotifers during the summer months. The Montana Fish and Game Department has studied the distribution, movements, and composition of fish populations along with physical and chemical characteristics of the lake since 1964, Hanzel, [15-25]. Potter has been studying the zooplankton distribution and ecology during the last two years (1971-1973,[26]).

Most of the recent works on the chemical and physical characteristics and the phytoplankton and zooplankton of Flathead Lake have been partially or wholly supported by grants from the Federal Water Quality Administration and its successor, the Environmental Protection Agency. A number of theses and research papers supported by these agencies are

by Moghadam,[4], Hern,[2], Morgan,[27,28], Ivory,[30], and Potter,[26].

While not supported directly by federal grant funds, the work of Dr. Gerald Prescott on the higher aquatic plants of Flathead Lake, that of Dr. Prescott and Dr. William Vinyard on the algae of Flathead Lake, and the work of D. A. Hanzel and his associates of the Montana Fish and Game Department on the fishes have contributed significantly to our knowledge of Flathead Lake. The results of their research will also be included in this report.

SECTION IV

STUDY OBJECTIVES AND APPROACH

OBJECTIVES OF STUDIES

The objectives of the studies conducted by Moghadam,[4], Morgan,[27,28], and Ivory,[30] were: (1) to determine the physical and chemical characteristics of the water, (2) to determine the standing crop of phytoplankton present during all seasons of the year, (3) to correlate these characteristics with the phytoplankton productivity of the lake, (4) to observe the succession, distribution, and diversity of the phytoplankton forms, (5) to determine the role of chemical nutrients in the relationship to the phytoplankton, and (6) to help establish guidelines for the chemicals dissolved in the lake's water during the different seasons of the year.

SAMPLING STATIONS

Due to the large size of Flathead Lake the studies conducted by Moghadam, Morgan, and Ivory were limited to sections of the lake most affected by man's activities. Stations where sampling was done are marked on the map (Plate 1) by triangles directed toward shoreline landmarks. The stations selected for sampling by Moghadam and Morgan were as follows:

1. Flathead River at Holt Bridge
2. Swan River at Ferndale Bridge
3. Mouth of Flathead River
4. Bigfork Bay
5. Mid-Lake Station between Angel Point and Yenne Point
6. Yenne Point southwest of Bigfork Bay
7. Wood Bay
8. Deep Water Station between Yellow Bay and Wildhorse Island
9. Yellow Bay

Moghadam's ecological and systematic study of plankton diatom communities in the lake covered an eight-week period during the summer of 1967. Weekly samples were collected from each station at four depths. For comparative purposes qualitative samples of phytoplankton were taken from five additional stations on a more limited basis. Morgan's study of phytoplankton productivity and dissolved nutrient levels was confined to the nine major sampling stations listed but in addition to the summer of 1967 comprised an intensive sampling period from June 18, 1968, through September, 1969. Ivory's study of phytoplankton productivity was confined to six sampling stations in Polson Bay during the period from June, 1970, through September, 1972.

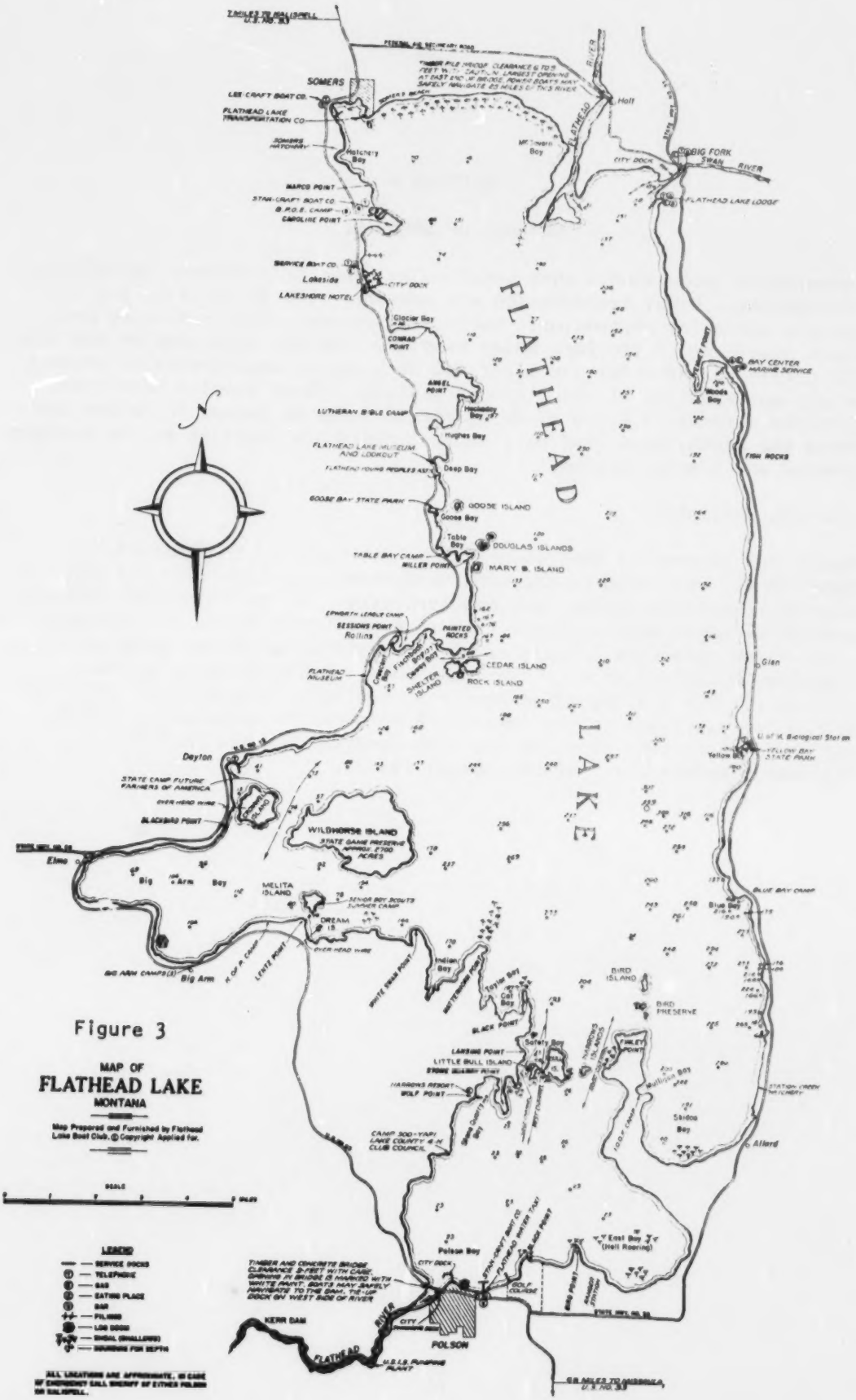

Figure 3

MAP OF
FLATHEAD LAKE
MONTANA

Map Prepared and Furnished by Flathead Lake Boat Club. © Copyright Applied for.

SECTION V

METHODS OF SAMPLING

Temperature measurements were obtained by means of a Foxboro conductivity thermometer. Light transmission was measured by a Secchi disc and a Gemware submarine photometer. Water samples were taken with a Kemmerer water bottle and a Van Dorn water sampler. The Van Dorn sampler was used for obtaining water for the light and dark bottle experiments to prevent metal contamination of the living organisms. Water samples were taken from the surface, 3 m, 10 m, 20 m, and 30 m depths except in Polson Bay where the depths were limited. Ivory limited his sampling to the surface, 3-meter and 5-meter depths.

CHEMICAL ANALYSES

Analytical procedures described in the Hach Chemical Engineers Kit, Model DR-EL, were used on the boat in determining alkalinity, carbon dioxide, dissolved oxygen, pH, and turbidity. In the laboratory 500 ml. samples of water were filtered through a millipore filter (R) having a 0.45 micron pore size. Analyses of the filtered water for chloride, fluoride, dissolved iron, nitrate, ammonia, orthophosphate, sulfate, silica, calcium and magnesium hardness were made in accordance with the procedures described by the American Public Health Association (1965) and modified in some cases by the Hach Chemical Company in their Engineer's Laboratory, Methods Manual 29.,[31].

SECTION VI

PHYTOPLANKTON PRODUCTIVITY

OXYGEN EVOLUTION METHOD

As one means of measuring phytoplankton productivity both Morgan and Ivory in their studies utilized the light and dark bottle evolution technique as described by Strickland,[32] for at least one summer during their research. Due to the oligotrophic nature of Flathead Lake the results were too variable to have significant value. Vollenweider,[33] indicated that, in deference to statistical considerations, there must be an arithmetical difference of at least 0.15 mg O_2/l between the light and dark bottles for the data to be considered significant. Utilizing incubation periods of from 4 to 24 hours both Morgan and Ivory found that very often such a difference in the content of dissolved oxygen did not occur.

CARBON 14 (C^{14}) UPTAKE

The assimilation of Carbon 14 (C^{14}) is a direct measure of the photosynthetic activity or organic productivity taking place in the aquatic environment. Steemann-Nielson,[34,35] developed this method for assessing algal productivity in the marine environment. The procedure is very similar to that of the oxygen evolution method, the difference being the injection of a specific quantity of radioactive C^{14} in the form of sodium carbonate ($Na_2C^{14}O_3$) in the light and dark bottles.

The field procedure involved taking water samples from various depths at each station with the Van Dorn bottle. Each sample was then used to fill two light and one dark bottles which were kept in a darkened area until the C^{14} solution was introduced into them. The bottles were left in the water to incubate for periods from 4 to 6 hours.

In the laboratory a 200 ml. aliquot of each sample was filtered through a 22 mm membrane filter using a field isopor filtration kit. The measurement of radioactivity of C^{14} labeled algae on the membrane filters was performed with a Geiger-Mueller counter by Morgan. Ivory in his work had access to a liquid scintillation spectrometer which proved to be considerably more efficient as a counting device.

PHYTOPLANKTON STANDING CROP

One-liter samples of water for phytoplankton analyses were taken at the various depths at each station. These samples were refrigerated until they could be concentrated and preserved. Phytoplankton was concentrated through the use of a Foerst continuous flow centrifuge. A 500 ml. aliquot of the sample was centrifuged for 4 minutes and the resulting concentrate was then diluted to 10 ml. and preserved in Transeau's

Solution consisting of water, 95% alcohol, and formaldehyde in a 6:3:1 proportion. The concentrated samples were stored in 6-dram vials until identification and enumeration of the plankton could be accomplished. Plankton counts were made with a Whipple disc and Sedgewick Rafter counting slide, using ten randomly selected fields. After ten fields were enumerated a strip count was made to include any genera which were too scarce to be detected in the Whipple disc counts. Species determinations were made by examining a drop of the plankton concentrate under 450X magnification. Raw counts were then converted to number per liter of lake water.

SECTION VII

PHYSICAL CHARACTERISTICS OF FLATHEAD LAKE

TEMPERATURE

The various studies that have been conducted on the lake have clearly demonstrated that it is a cold dimictic lake exhibiting submerged depression individuality. There are various bays and depressions in the lake each of which may have its own thermocline that differs in position and thickness in the different depressions, and each depression may have its own individual seasonal history. Furthermore, while much of the lake stratifies thermally, there are several extensive shallow bays such as Polson Bay which do not do so.

Morgan,[27,28] found considerable variation in temperature between the stations which he studied. Temperatures at the surface during the peak summer stratification on August 6, 1968, reached a high of 21°C at four of nine stations, with the remaining stations ranging from 17°C in the Flathead River to 20.5°C at the Mid-Lake Station. Hypolimnion temperatures reached 9.0°C at the 35-meter depth in the bay stations and mouth of the Flathead River. The deep H_2O and Mid-Lake stations reached 7.0°C during the peak period. Water samples taken at the deep H_2O Station, June 20, 1969, from the 40-meter, 50-meter, and 60-meter depths had temperatures of 4.3°C, 4.6°C, and 4.7°C respectively.

Whereas a distinct thermocline can be found in various depressions of the lake each summer, its depth, period of formation, and the spring and fall overturns vary considerably from year to year. In 1968 the thermocline began forming the last week in June and persisted until the beginning of October of that year in the deep H_2O Station. The fall overturn began during the last week of September. This mixing continued until the first week of November when the lake was homothermous from top to bottom.

Inverse stratification of the lake began in late December, 1968. The bay areas of the lake began freezing over, a normal occurrence for the lake at this time. Extreme cold persisted with air temperatures reaching as low as -37°C during the months of December and January. The lake proper began freezing over during the month of January and had a complete ice cover from the last week of January until the first week of April when the ice cover began to break up. The formation of a complete ice cover is uncommon on the lake. This was the first complete icing of Flathead Lake in 23 years.

The spring turnover began shortly after the ice break-up with homothermous conditions occurring during the middle of May. The lake did not stratify during the summer of 1969 until the first week of July.

LIGHT TRANSMISSION

The oligotrophic waters of Flathead Lake offer little interference to light waves impinging on the lake's surface. Low levels of dissolved solids and color-producing compounds plus limited plankton allow measurable light to penetrate to depths of 60 meters. During a calm period on July 23, 1969, Morgan found 71% light transmission at a depth of 10 meters and 4% transmission at 50 meters at a deep H_2O Station.

The lower limit of the euphotic zone as defined by Reid,[36] is that point at which only 1% of the total incident surface radiation is measurable. The transmittance of light in Polson Bay, which during the summer months is often much more turbid than the lake proper, was found by Ivory,[30] to range from 100.0% near the surface to 6.7% near the bottom (7 meters). Thus even more shallow freely mixing areas of the lake appear to be well within the euphotic zone.

SECTION VIII

CHEMICAL CHARACTERISTICS OF FLATHEAD LAKE

The dilute chemical composition of the waters of Flathead Lake might be expected considering the drainage basin which is composed of sedimentary rock with thin soils and subsoils of gravelly glacial debris and impermeable bedrock. Furthermore, the streams draining into the lake are relatively short and arise from snow and ice melt and from cold mountain springs. Consequently, there is little opportunity for the inlet waters to have gathered high concentrations of solutes.

In 1929 Howard, working with Clapp, Elrod, Young, and Shallenburger, conducted a survey of the lake (Clapp, C. H. et al.,[27]). Dr. Howard was responsible for the chemical determinations during the study. Morgan,[28] summarized the results of chemical analyses of the lake conducted at various times since Howard's work. The summary (Table 1) indicates that little change has occurred in the chemical composition of the waters of the main body of the lake over the last forty years.

The results of Ivory's study of Polson Bay are included in Table 3 for comparative purposes. Concentrations of some nutrients as ammonia and nitrate nitrogen were slightly less than in other areas of the lake. This may have resulted from nutrient utilization by Chara and higher aquatic plants which occur abundantly in the shallow waters of the bay.

Table 3. FLATHEAD LAKE WATER CHEMISTRY
Forty Year Span
(mg/l)

	Howard 1929	Potter & Baker 1961	Morgan 1967	Morgan 1968	Morgan 1969	Ivory 1971-72
Aluminum	9.3	a	0.04	0.04	0.03	a
Ammonia-Nitrogen	0.13	0.01	0.32	0.25	0.23	0.04
Bicarbonate	-	10.2-85.7	80.0	80.0	75.0	81.0
Carbon Dioxide	2.0	0.0	Trace	0.0[b]	0.0	0.8
Carbonate	20.5	4.0	10.0	7.5	5.0	2.8
Chloride	0.32	a	0.50	1.00	0.75	a
Dissolved Oxygen	8.0	11.0	10.3	10.8	10.5	9.0
Iron Total	0.02	0.60	0.10	0.05	0.05	0.02
Nitrate-Nitrogen	Trace	0.05	0.16	0.12[b]	0.19	0.06
Nitrite-Nitrogen	-	Trace	Trace	Trace	Trace	Trace
Phosphate-Ortho	Trace	0.20	0.16	0.11	0.15	0.035
Silicate	8.2	a	5.0	4.7	4.5	4.6
Sulfate	24.9	a	5.5	7.0	6.8	5.4
pH[c]	8.4[c]	8.0[c]	8.3-8.7[c]	8.2-8.7[c]	8.3-8.8[c]	8.0-8.4[c]

[a] Not determined by researcher
[b] Denotes extremes not included
[c] pH expressed in units

SECTION IX

PHYTOPLANKTON DISTRIBUTION IN FLATHEAD LAKE

Dr. Moghadam,[4] in her systematic study of the diatom communities of Flathead Lake identified 337 different taxa of which five species and two varieties were new. Dr. Morgan,[27,28] in his study of phytoplankton productivity of the lake identified a total of 199 species and varieties. Five divisions of algae were encompassed in his enumeration. Deletion of species common to both studies yields a combined total of 503 different species and varieties of algae found in Flathead Lake's phytoplankton population.

DOMINANT SPECIES OF CHRYSOPHYTA

The planktonic algae which exhibited dominance throughout Morgan's study were almost entirely of the subdivision Bacillariophyceae. The genera most frequently encountered were: Asterionella, Fragilaria, Rhizosolenia, Synedra, and Tabellaria, with occasional appearances of Cyclotella, Navicula, Cymbella, Campylodiscus, Surirella, Gyrosigma, and Eunotia. Other algae encountered frequently of the same division, Chrysophyta, subdivision Chrysophyceae, were four species of the same genera: Dinobryon bavaricum Imhof, D. divergens Imhof, D. sertularia Ehrenberg, and D. sociale Ehrenberg. Other genera of the same subdivision, but which occurred less frequently, were Mallomonas, Rhizochrysis, and Synura. The total number of species identified in the order Chrysophyta was 109.

The Cyanophyta or blue-green algae most often found were Chroococcus, Gomphosphaeria, Gloeocapsa, Microcystis, Merismopedia and on occasions Spirulina, Anabaena, Aphanocapsa, and Aphanizomenon. Aphanizomenon occurred one time only in the phytoplankton of Flathead Lake. The blue-green algae did not exhibit any dominancy except for one bloom of Aphanizomenon flos-aquae Ralfs in late summer. The bloom occurred just to the west of Bigfork Bay. This area is relatively shallow (2-8 m) and is exposed to the diurnal mixing action of the south wind. The continual eddying returns the nutrients from the sediments to the water above for algal utilization.

The blue-green algae occurred most frequently in the late summer and early fall when the nutrients were at their lowest concentrations. Chroococcus limnetica Lemmermann, C. prescottii Drouet & Daily, and Aphanocapsa elastista G. M. Smith were the most common species found in the pelagic zone of the lake.

A total of 25 species was identified during the study of which 10 were rather rare in occurrence. Genera, such as Dactylococcus, Eucapsis, Gloeotrichia, Lyngbya, and Synechococcus appeared rarely and then only in limited numbers.

The division Chlorophyta (green algae) was even less frequently found in the planktonic samples of Flathead Lake. Oocystis spp. were the most frequent, followed by Spaerocystis, Cosmarium, Pediastrum, and Staurastrum. Dictyosphaerium pulchellum Wood was often found in samples containing Chroococcus spp. during the late summer months. The remaining species were infrequent and were transported largely from areas along the shoreline or rivers to the pelagic region of the lake. Filamentous species, such as Mougeotia genuflexa (Dillw.), Zygnema pectinatum Fritsch & Stephens represent such transported species. These species are sessile forms commonly found along the shore areas.

Sixty-three different species of green algae were found in the plankton samples during the study.

The small division Pyrrophyta was well represented with five genera and 14 species. Most commonly encountered were the species Ceratium hirundinella, Glenodinium kulczynskii (Wolosz.) Schiller, and Peridinum cinctum var. tuberosum (Meunier) Linderman. This division is limited in numbers during the spring. The increased temperatures of summer and possibly the increased organic compounds (Hutchinson,[38]) released by previous plankters facilitate these plankters' growth and reproduction.

The fifth and smallest division Euglenophyta was represented by only one genera, Trachelomonas sp., at the Bigfork Bay Station. This division undoubtedly has many more species in the shoreline areas where more organic matter is available for their use.

ECOLOGICAL RELATIONSHIPS

In planktonic studies of algae certain species appear to be associated with one another. The name of the dominant species or sometimes the dominant and subdominant are used as designations for the association. Hutchinson,[38] uses this form naming the dominant species and then the subdominant, e.g., Fragilaria-Asterionella; Fragilaria being the dominant and Asterionella the associated subdominant. One or more subdominants may be associated. This type of association was used in showing relationships between genera found during the study.

The species showing dominance during the study were Tabellaria quadrisepta Knudson, Fragilaria crotonensis Kitton, Rhizosolenia eriensis H. L. Smith, Dinobryon divergens, Stephanodiscus sp., Asterionella formosa. Each of these genera showed pulses during the study but none were strong enough to exhibit a bloom.

Tabellaria quadrisepta occurred in its greatest numbers during June and early July. The largest population of this species, 186, 189 per liter, occurred at the Deep H_2O 30 m level. Computer data indicates this species as being a cold water, high nutrient requiring species.

Fragilaria crotonensis exhibited a pulse during late June in 1968 and 1969. This species exhibited another pulse shortly after the fall turn-

over each year.

Dinobryon bavaricum and D. sociale showed preference for colder temperatures and higher nutrient levels than D. divergens or D. sertularia. Silicon dioxide levels are known to limit D. divergens.

Rhizosolenia eriensis, a diatom of the order Centrales, showed high population figures shortly after the ice breakup in the spring of 1969. Another pulse was detected during the summer when nutrients are more limited. Pearsall,[39] reported R. eriensis as requiring less nutrients than Asterionella formosa, Fragilaria crotonensis and Tabellaria fenestrata.

Asterionella formosa, a pennate form of the family Fragilariaceae, was found throughout the study. Asterionella formosa is considered to be a cold water form requiring high nutrient levels. This species during the summer is a subdominant associated with all the species described previously. Concentration of A. formosa fluctuated throughout the study with a general increase being noted after late August. The increase of A. formosa can be attributed to increase of dissolved nutrients two weeks prior to the pulse.

Synedra delicatissima W. Smith and S. fasciculata var. fasciculata (Ag.) Kuts. were found in numbers totaling 174,000 and 34,800 per liter respectively during and shortly after the spring thaw of 1969. The Synedra spp. showed a decline with the decreasing of silica, nitrate and sulfate in the summer months. S. acus var. acus Kutz. was limited mainly to the rivers and those stations more directly influenced by the rivers.

Other diatoms of the order Pennales that appeared commonly in the plankton samples were the genera Amphora, Cymbella, Navicula and Pinnularia; other pennale genera were identified but occurred less frequently.

Cymbella and Navicula appeared in minor concentrations throughout the study. Both general, although usually free-floating, are often found attached to submerged objects, which accounts for limited numbers in plankton samples. Both genera were found in plankton samples at each station sporadically.

Cyclotella and Melosira, of the order Centrales, occurred at all stations and the various depths sampled. Melosira, a diatom forming a filamentous chain, is considered to be a cold water, high nutrient-demanding diatom. Melosira occurred in limited numbers at all stations and depths. The nutrient level required, plus the physiological structure influenced by density, limits Melosira to periods of seasonal overturn. Cyclotella appeared in increased numbers during the late summer and fall periods similar to the distribution patterns of Stephanodiscus.

Dr. Ivory,[30] conducted his limnological studies of Polson Bay from June 1970 to September 1972 and encountered phytoplankton populations some-

what different than those found in the upper deeper sections of the lake by Morgan. Polson Bay is located in the southern end of Flathead Lake and has a gently sloping muddy bottom and a maximum depth of only 7 meters. Much of the bottom is covered with sizeable growths of Chara, Potamogeton, Ceratophyllum, and Myriophyllum. During the fall and winter months much of the bottom area is left dry and exposed by the receding waters of the lake.

Ivory reported 67 genera and 94 species of algae in Polson Bay. The Bacillariophyceae and the Chlorophyceae were the most abundant groups, and the diatoms contributed more than 50% of the total population during each year of the study. The composition of the phytoplankton varied somewhat from year to year as did the size of the standing crop, but no definite pattern of change in productivity was evident. Populations trends during the spring and summer periods of the three years appeared to follow a similar pattern with an increase in the population size in late spring or early summer. This increase was followed by a steady decline in the population until early autumn. During 1970 a definite fall maximum was observed; during 1971 the seasonal sample obtained in October indicates that such an autumnal increase had probably occurred somewhat earlier. In 1972 sampling was terminated in late August before any such seasonal increase in population had occurred.

During the three-year period, the concentration of phytoplankton appeared to be slightly greater at depths of 3, 5, or 7 meters than near the surface, but no station had a consistently greater plankton population than any other.

During July 1970, increases in the populations of Dinobryon divergens, Tabellaria quadrisepta, and Cyclotella spp. led to a phytoplankton maximum. In September and October another maximum was observed. During this autumn maximum, many of the organisms reached their greatest abundance. Thus, Tabellaria quadrisepta, Cyclotella spp., Fragilaria crotonensis, Navicula spp., Rhizosolenia eriensis, Gomphosphaeria aponina Kuetz, Gomphosphaeria lacustris Chodat, Mallomonas pseudocoronata Prescott, Mallomonas alpina Pascher and Ruttner, Ceratium hirudinella, and Synedra spp. attained their maximum abundance during the fall. The organisms which dominated the fall maximum were Tabellaria quadrisepta Knuds, Cyclotella spp., Gomphosphaeria aponina, G. lacustris, Dinobryon divergens Bachm., and Fragilaria crotonensis Kitton.

A rank of the most abundant species during each year of the study is given in Table 4.

Although the overall population patterns appeared to be similar from year to year, the absolute abundance of the standing crop and the dates at which maxima and minima occurred were slightly different from year to year. Thus, the absolute abundance of phytoplankton during the spring-summer maximum of 1971 was considerably larger than the maxima of 1970 or of 1972, and it occurred at a slightly different date than either of the others.

Table 4. RANK OF PHYTOPLANKTON SPECIES ACCORDING TO MEAN POPULATION (number of organisms/l x 10^2)

Taxon		Mean	Maximum
Dinobryon divergens	1970	222.0	1183.0
Tabellaria quadrisepta	"	183.0	833.0
Gomphosphaeria spp.	"	113.0	482.0
Cyclotella spp.	"	91.0	351.0
Navicula spp.	"	65.6	482.0
Fragilaria crotonensis	"	50.8	438.0
Tabellaria quadrisepta	1971	577.0	1464.0
Cyclotella spp.	"	467.0	2063.0
Dinobryon divergens	"	212.0	499.0
D. bavaricum	"	111.0	766.0
Navicula spp.	"	109.6	2463.0
Chroococcus spp.	"	102.8	300.0
Synedra spp.	"	93.9	900.0
Cyclotella spp.	1972	396.0	1281.0
Dinobryon divergens	"	229.0	525.0
Synedra spp.	"	132.0	854.0
Dinobryon bavaricum	"	124.0	493.0
Tabellaria quadrisepta	"	116.0	493.0
Rhizosolenia eriensis	"	87.0	296.0
Chroococcus spp.	"	56.5	1478.0

The composition of the phytoplankton standing crop also differed somewhat from year to year. Thus, the Myxophyceae comprised a larger percentage of the total population in 1970 than in either 1971 or 1972. On the other hand, the Dinophyceae contributed a larger percentage of the population in 1972 than they did in 1970. Such yearly differences in the composition of the standing crop may result in part from a sampling bias since the early and late sampling periods of each year do not coincide exactly. Also, slight differences in such environmental parameters as temperature and light probably account for such differences in composition.

SECTION X

ALGAL FLORA OF FLATHEAD LAKE

The algal flora of Flathead Lake, both quantitatively and qualitatively, reflects its limnological and hydrographic uniqueness. This is notwithstanding that every lake possesses its own combination of physiochemical characteristics. But these hydrographic and physiographic features seem to have some significant influences which help to explain the somewhat unusual biotic composition and distribution of algae throughout the lake.

First, it is seldom that a lake with the volume of the Flathead lies so near the headwaters of its tributaries. In this instance the streams draining into the lake are relatively short, and they arise from snow and ice melt and from cold mountain springs. Accordingly the inlet waters 1) are relatively cool, and 2) have little opportunity to become heavily silted or to have gathered high concentrations of solutes. The turbidity readings for the two principal tributaries (Swan River, Flathead River) for example are relatively low (Table 5) and in general are much less (at the same time of year) than at many stations throughout the lake. Likewise, phosphates and nitrates are low, those for the Flathead River being slightly but not significantly greater than in the Swan River. The temperature of inlet waters averages slightly higher than at stations throughout the lake during the spring run-off (Table 6). Throughout the lake the surface layer temperature seldom reaches 20°C throughout the summer, whereas at 30 M, where the algal population is often greater in numbers of individuals than at the surface, the temperature does not rise above 13°C and seldom reaches that level. The relatively deep basin contributes to and maintains the low temperature of Flathead Lake (Table 6) and determines some of the oligotrophic features of the lake.

Secondly, Flathead River which flows into and out of the lake produces a strong channel current. This has an unknown effect on the systems of currents both vertical convection and horizontal. But it seems obvious that the distribution pattern of phytoplankton species is influenced by and determined in part by currents. For example, it is likely that the unusual density of plankters in the 25-30 M zones is related to lake currents (Tables 11-13). In addition to currents influenced by channel flowage, distribution is influenced (to an unknown extent) by strong and frequent wind action which produces oceanic effects in the surface waters periodically. Such action also has a bearing on water mixing and the level of the thermocline which in turn has both direct and indirect effects on the distribution of organisms.

Another factor which has interacting effects is the fluctuation of the water level in Flathead Lake. Operation of a power dam in the outlet causes the lake level to drop from 10 to 12 feet during the winter and early spring months, in all about 7 months of the year. This has an

Table 5. TURBIDITY J.T.U.

Station	Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Swan River	S[a]	5.0	7.0	0.0	4.0	3.0	5.0	7.0	12.0	8.0	9.0	4.0	1.0	5.0	5.0	10.0	c	c	c	8.0	10.0	6.0
	3	6.0	4.0	8.0	10.0	6.0	5.0	5.0	12.0	7.0	10.0	8.0	2.0	0.0	5.0	11.0	c	c	c	8.0	9.0	6.0
Flthd River	S[a]	15.0	8.0	5.0	4.0	7.0	7.0	4.0	6.0	4.0	5.0	25.0	17.0	10.0	4.0	7.0	c	c	c	12.0	22.0	14.0
	3	18.0	5.0	0.0	8.0	6.0	4.0	4.0	6.0	6.0	4.0	28.0	17.0	9.0	1.0	8.0	c	c	c	15.0	25.0	17.0
	9	19.0	4.0	0.0	6.0	5.0	4.0	5.0	7.0	5.0	5.0	25.0	18.0	13.0	4.0	10.0	c	c	c	21.0	37.0	30.0
Mth of Flthd	S[a]	10.0	3.0	20.0	8.0	12.0	8.0	4.0	1.0	5.0	1.0	20.0	17.0	0.0	b	12.0	c	c	c	12.0	14.0	10.0
	3	14.0	3.0	8.0	10.0	13.0	8.0	4.0	9.0	9.0	2.0	22.0	15.0	0.0	b	8.0	c	c	c	12.0	18.0	12.0
	10	15.0	8.0	18.0	14.0	10.0	12.0	3.0	8.0	13.0	8.0	23.0	7.0	0.0	b	5.0	c	c	c	11.0	14.0	16.0
	20	16.0	3.0	20.0	9.0	9.0	6.0	1.0	7.0	9.0	11.0	26.0	10.0	0.0	b	2.0	c	c	c	10.0	15.0	12.0
	30	15.0	12.0	20.0	30.0	d	19.0	8.0	4.0	9.0	1.0	33.0	8.5	2.0	b	3.0	c	c	c	12.0	14.0	13.0
Bigfork Bay	S[a]	14.0	5.0	22.0	9.0	10.0	26.0	7.0	1.0	20.0	2.0	26.0	11.0	3.0	b	4.0	c	c	c	10.0	12.0	11.0
	3	14.0	6.0	23.0	20.0	25.0	28.0	9.0	3.0	22.0	3.0	27.0	10.0	3.0	b	2.0	c	c	c	10.0	14.0	10.0
	4	11.0	18.0	17.0	14.0	17.0	21.0	7.0	3.0	20.0	5.0	38.0	17.0	0.0	b	5.0	c	c	c	9.0	15.0	13.0
Mid-Lake	S[a]	15.0	13.0	2.0	1.0	2.0	2.0	5.0	7.0	12.0	2.0	9.0	7.0	9.0	b	8.0	c	c	c	4.0	10.0	8.0
	3	11.0	17.0	0.0	19.0	1.0	4.0	8.0	7.0	13.0	5.0	12.0	8.0	9.0	b	10.0	c	c	c	6.0	8.0	6.0
	10	13.0	16.0	2.0	15.0	1.0	9.0	4.0	1.0	15.0	8.0	10.0	5.0	8.0	b	8.0	c	c	c	4.0	7.0	3.0
	20	12.0	17.0	5.0	13.0	1.0	5.0	8.0	2.0	13.0	6.0	15.0	10.0	9.0	b	1.0	c	c	c	2.0	8.0	3.0
	30	16.0	17.0	1.0	11.0	1.0	10.0	0.0	3.0	8.0	7.0	21.0	13.0	1.0	b	3.0	c	c	c	2.0	8.0	5.0
Yenne Point	S[a]	16.0	10.0	5.0	17.0	10.0	6.0	7.0	8.0	10.0	19.0	22.0	10.0	0.0	b	4.0	c	7.0	3.0	14.0	12.0	6.0
	3	11.0	10.0	10.0	12.0	5.0	7.0	3.0	10.0	3.0	21.0	24.0	12.0	1.0	b	4.0	c	5.0	2.0	10.0	12.0	8.0
	10	10.0	8.0	11.0	17.0	14.0	8.0	3.0	9.0	5.0	16.0	21.0	7.0	1.0	b	2.0	c	4.0	3.0	8.0	14.0	12.0
	20	8.0	4.0	1.0	8.0	9.0	14.0	12.0	8.0	5.0	17.0	14.0	5.0	2.0	b	2.0	c	4.0	1.0	5.0	5.0	14.0
	30	7,0	6.0	1.0	1.0	2.0	7.0	1.0	8.0	3.0	16.0	14.0	8.0	1.0	b	3.0	c	2.0	2.0	4.0	6.0	6.0

Table 5 (continued). TURBIDITY J.T.U.

Station	Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Woods Bay	S[a]	7.0	10.0	0.0	2.0	12.0	18.0	3.0	6.0	3.0	10.0	0.0	8.0	4.0	b	4.0	c	15.0	18.0	0.0	1.0	2.0
	3	7.0	8.0	3.0	3.0	10.0	9.0	6.0	7.0	2.0	8.0	2.0	7.0	4.0	b	6.0	c	17.0	20.0	1.0	8.0	2.0
	10	8.0	5.0	5.0	10.0	8.0	9.0	7.0	8.0	5.0	8.0	0.0	6.0	1.0	b	1.0	c	21.0	19.0	1.0	10.0	3.0
	20	5.0	9.0	0.0	0.0	9.0	10.0	8.0	8.0	1.0	9.0	3.0	4.0	2.0	b	7.0	c	10.0	12.0	0.0	8.0	4.0
	30	6.0	9.0	0.0	0.0	7.0	7.0	4.0	8.0	3.0	10.0	8.0	4.0	6.0	b	10.0	c	18.0	22.0	0.0	10.0	1.0
Deep H_2O	S[a]	8.0	9.0	8.0	10.0	8.0	8.0	7.0	3.0	10.0	1.0	3.0	5.0	12.0	b	15.0	c	c	c	6.0	1.0	4.0
	3	8.0	7.0	2.0	17.0	12.0	8.0	8.0	3.0	12.0	4.0	6.0	3.0	9.0	b	10.0	c	c	c	5.0	3.0	4.0
	10	8.0	8.0	7.0	9.0	15.0	11.0	6.0	3.0	15.0	5.0	7.0	5.0	10.0	b	8.0	c	c	c	5.0	6.0	7.0
	20	4.0	6.0	6.0	7.0	11.0	12.0	18.0	0.0	10.0	2.0	3.0	5.0	9.0	b	4.0	c	c	c	10.0	3.0	1.0
	30	8.0	8.0	7.0	5.0	1.0	4.0	2.0	4.0	10.0	1.0	7.0	4.0	9.0	b	10.0	c	c	c	7.0	4.0	1.0
Yellow Bay	S[a]	3.0	2.0	2.0	1.0	2.0	4.0	2.0	10.0	11.0	10.0	8.0	9.0	6.0	b	7.0	c	5.0	1.0	5.0	4.0	2.0
	3	2.0	4.0	5.0	1.0	5.0	8.0	1.0	10.0	10.0	2.0	4.0	4.0	8.0	b	7.0	c	6.0	8.0	2.0	3.0	2.0
	10	3.0	5.0	7.0	5.0	10.0	6.0	6.0	7.0	8.0	5.0	4.0	5.0	4.0	b	6.0	c	4.0	15.0	4.0	5.0	2.0
	20	3.0	6.0	8.0	1.0	10.0	4.0	1.0	6.0	5.0	4.0	8.0	5.0	8.0	b	6.0	c	14.0	16.0	2.0	1.0	4.0
	30	3.0	3.0	4.0	4.0	9.0	4.0	5.0	8.0	7.0	1.0	4.0	5.0	4.0	b	3.0	c	13.0	20.0	1.0	3.0	4.0

[a] Surface

[b] Lake was too rough

[c] Beginning of continued ice cover

[d] Too shallow

Table 6. THERMAL READINGS
(°C)

Station	Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Swan River	Air	16.5	16.0	27.0	21.0	22.5	25.0	18.0	15.5	8.5	8.5	9.5	10.0	-2.0	2.0	-4.0	c	c	c	9.0	22.0	8.0
	S[a]	12.3	13.0	14.1	16.0	18.5	21.0	17.0	16.0	11.7	11.5	13.0	8.5	6.5	6.0	4.8	c	c	c	5.0	11.8	10.8
	3	11.9	12.7	14.3	16.8	18.0	21.0	16.5	16.5	13.0	12.0	13.0	8.5	6.5	6.0	4.0	c	c	c	5.1	12.4	11.5
Flthd River	Air	15.0	16.0	27.0	22.0	25.0	26.0	24.0	25.0	22.0	18.0	10.0	10.0	-5.0	2.0	-5.0	c	c	c	9.0	22.0	6.9
	S[a]	9.5	10.0	11.0	12.0	13.0	17.0	21.0	20.0	17.0	16.0	14.0	8.5	7.0	7.5	3.4	c	c	c	5.7	9.1	10.0
	3	9.3	10.0	10.5	12.5	12.0	16.5	20.0	20.5	16.0	16.0	13.0	8.0	7.0	6.8	4.0	c	c	c	5.7	8.7	10.0
	9	8.7	9.0	10.5	12.5	12.0	15.0	20.0	20.0	16.0	16.0	13.0	8.2	7.0	7.0	4.8	c	c	c	5.7	9.0	9.8
Mth of Flthd	Air	16.8	16.2	34.0	30.6	23.9	23.0	21.0	33.0	16.0	19.0	18.0	5.0	2.0	b	3.7	c	c	c	14.0	23.9	17.0
	S[a]	11.2	12.8	14.4	18.9	17.9	21.0	18.0	19.5	19.0	11.0	12.5	8.0	7.0	b	6.3	c	c	c	2.9	10.0	12.8
	3	8.7	12.2	13.1	16.7	16.1	21.0	18.0	19.0	19.0	13.0	12.5	8.3	7.5	b	6.3	c	c	c	2.9	6.1	12.7
	10	6.2	10.0	9.0	7.8	14.4	20.0	18.0	19.0	18.5	12.0	12.5	8.5	7.5	b	6.0	c	c	c	3.0	3.9	9.0
	15	4.6	5.6	6.2	6.1	10.6	16.2	16.5	18.7	18.3	13.0	12.5	8.5	7.5	b	6.0	c	c	c	3.9	3.9	6.0
	20	3.9	3.9	5.6	5.6	8.9	11.4	10.0	18.5	18.0	15.0	12.0	8.5	7.5	b	5.8	c	c	c	3.9	3.9	5.3
	25	3.8	3.9	4.6	5.6	7.2	10.3	9.3	15.0	15.5	13.0	12.5	8.2	7.8	b	5.8	c	c	c	4.0	3.9	3.8
	30	3.8	3.8	4.0	5.6	d	10.0	9.0	12.0	13.0	9.0	12.5	8.0	8.0	b	5.8	c	c	c	4.0	3.9	3.8
	35	3.8	3.8	4.0	5.6	d	7.8	6.1	8.0	9.0	9.0	9.0	8.0	8.0	b	5.8	c	c	c	4.0	3.9	3.8
Bigfork	Air	18.0	15.4	32.0	29.0	25.0	24.0	18.0	27.0	18.0	8.5	18.0	11.0	0.0	b	-2.0	c	c	c	13.0	20.0	14.0
	S[a]	12.3	12.1	15.2	18.0	18.0	20.0	18.0	18.0	17.0	11.0	11.5	8.0	7.0	b	2.5	c	c	c	5.0	14.0	12.0
	3	10.8	12.0	14.3	17.5	15.5	21.0	18.0	18.0	17.0	12.0	11.0	8.5	7.5	b	2.8	c	c	c	5.2	14.0	11.5
	4	10.8	11.7	14.3	15.0	15.0	20.5	18.0	18.0	17.0	9.0	11.0	8.0	7.5	b	3.2	c	c	c	4.8	14.0	10.8
Mid-Lake	Air	17.0	16.1	37.2	24.4	24.0	23.5	21.0	30.0	17.0	19.0	16.0	7.0	0.0	b	-10.0	c	c	c	15.0	24.4	16.0
	S[a]	11.7	14.4	18.9	20.0	19.0	20.5	20.1	19.0	19.0	13.0	12.7	8.2	6.8	b	5.5	c	c	c	3.0	10.0	12.8
	3	10.6	13.9	16.7	18.3	18.0	20.0	19.7	19.0	19.0	13.0	12.5	8.5	6.8	b	5.5	c	c	c	3.0	7.2	12.0
	10	6.7	7.8	12.8	14.4	16.0	15.0	18.0	18.0	18.5	12.0	12.5	8.5	6.8	b	5.8	c	c	c	3.8	4.4	9.2
	15	5.8	6.1	10.0	8.9	11.5	10.9	12.8	15.0	18.5	12.0	12.5	8.5	6.8	b	5.8	c	c	c	3.9	3.9	7.2
	20	5.0	5.0	8.3	7.2	11.0	10.0	11.8	12.0	18.5	12.0	12.5	8.5	6.8	b	5.9	c	c	c	4.0	3.9	5.3
	25	4.8	4.4	7.2	6.1	9.6	8.6	8.9	8.7	9.6	11.5	11.8	8.3	7.0	b	6.0	c	c	c	4.0	3.9	5.0
	30	4.0	4.4	6.1	5.7	8.0	7.0	8.0	8.0	9.0	11.0	9.5	8.0	7.0	b	6.0	c	c	c	4.0	3.9	3.9
	35	4.0	3.8	5.5	5.0	5.0	6.0	6.8	5.6	6.0	6.8	7.2	7.0	7.0	b	6.0	c	c	c	4.0	3.9	3.9
Yenne Point	Air	18.9	16.1	17.8	28.9	17.8	19.5	18.0	21.0	17.0	9.5	13.0	6.0	2.0	b	1.7	c	-12.0	-7.0	19.0	22.0	12.0
	S[a]	15.6	16.7	18.0	19.4	15.6	21.0	18.0	18.0	19.0	13.5	12.5	8.0	6.0	b	5.0	c	0.0	0.0	3.0	13.0	11.0
	3	15.0	16.1	17.0	18.3	15.0	20.0	19.0	18.0	19.0	14.0	12.0	8.0	6.0	b	5.5	c	1.2	1.2	3.0	9.0	8.0
	10	11.7	10.6	12.0	12.2	13.9	18.0	19.0	17.0	18.0	13.0	12.5	8.5	7.0	b	5.7	c	1.6	1.5	3.1	5.9	5.0

Table 6 (continued). THERMAL READINGS (°C)

Station	Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Yenne Point	15	10.0	7.8	11.0	9.4	10.6	10.8	11.0	12.5	12.7	12.5	12.5	8.5	7.0	b	5.5	c	3.0	2.8	3.1	5.7	4.5
	20	8.3	7.2	8.0	7.8	7.8	9.4	10.0	11.0	11.2	8.5	9.0	8.5	7.0	b	5.5	c	3.5	3.1	3.7	5.5	4.5
	25	7.2	6.7	7.4	6.7	7.4	9.0	9.0	9.2	8.5	8.5	8.5	8.5	7.5	b	5.5	c	3.5	3.1	4.0	5.2	4.5
	30	5.0	6.1	6.0	6.1	6.7	7.2	8.2	8.5	8.3	8.4	8.3	8.3	7.5	b	5.6	c	4.0	4.0	4.0	5.0	4.5
	35	5.0	6.1	6.0	5.5	5.6	6.0	7.0	7.2	7.6	7.6	7.3	7.3	7.0	b	5.8	c	4.0	4.0	4.0	4.0	4.5
Woods Bay	Air	19.0	16.5	23.3	17.2	21.7	17.0	20.0	22.0	19.0	9.5	13.0	7.0	2.0	b	-10.0	c	-12.0	-7.0	19.0	23.0	12.5
	S[a]	15.0	17.0	18.3	17.2	16.7	21.0	20.0	20.0	19.0	13.0	12.5	8.0	6.5	b	5.5	c	0.0	0.0	2.9	19.0	10.0
	3	13.8	16.1	16.1	16.8	16.1	20.0	19.0	19.0	19.0	13.5	12.5	8.0	6.5	b	5.5	c	1.1	1.2	3.1	10.0	9.0
	10	7.8	10.6	12.2	12.2	13.0	15.0	18.0	18.5	19.0	13.5	12.5	8.5	7.0	b	5.8	c	1.5	1.7	3.1	5.9	9.0
	15	7.2	7.2	10.0	10.5	10.0	10.0	13.0	13.0	18.5	13.5	12.5	8.5	7.0	b	5.8	c	2.8	3.0	3.1	5.7	7.0
	20	6.7	6.7	8.9	8.3	9.4	9.4	11.0	11.0	17.2	13.5	12.0	8.5	7.0	b	5.9	c	3.8	3.5	3.1	5.5	5.5
	25	5.7	6.1	8.3	8.3	7.8	9.0	10.0	10.6	15.0	13.5	12.0	8.5	7.0	b	6.0	c	3.8	3.8	3.7	5.2	5.5
	30	5.2	5.2	7.2	7.2	6.8	7.2	9.0	9.0	10.0	12.0	12.0	8.3	7.0	b	6.0	c	4.0	4.0	4.0	5.0	5.5
	35	5.0	5.2	6.7	6.7	5.6	6.1	7.0	7.2	9.0	9.0	9.0	8.0	7.0	b	6.0	c	4.0	4.0	4.0	4.0	4.0
Deep H_2O	Air	18.3	27.8	17.8	26.1	20.0	24.0	20.0	20.6	16.0	6.0	12.5	7.0	2.0	b	5.0	c	c	c	14.0	20.0	13.5
	S[a]	15.6	18.9	16.7	19.4	20.0	20.0	20.0	19.0	17.0	12.0	12,0	8.0	6.0	b	5.0	c	c	c	3.9	13.9	12.8
	3	14.4	16.1	15.6	18.3	19.0	20.0	20.0	19.0	17.0	12.0	12.0	8.0	6.0	b	6.0	c	c	c	3.0	11.1	12.2
	10	10.6	11.1	11.7	15.6	18.0	19.0	19.0	19.0	17.0	13.0	12.0	8.5	6.5	b	6.0	c	c	c	3.1	8.9	10.0
	15	7.8	11.1	9.4	10.6	13.0	15.0	15.6	16.1	15.5	13.0	12.0	8.5	7.0	b	6.0	c	c	c	3.1	7.1	9.0
	20	7.2	7.2	6.7	7.2	12.0	14.0	14.0	14.4	14.0	13.0	12.0	8.5	7.0	b	6.0	c	c	c	3.7	6.0	7.8
	25	6.7	7.2	6.1	6.7	7.2	9.4	9.0	9.4	9.4	9.0	9.0	8.3	7.0	b	6.0	c	c	c	4.0	5.2	6.0
	30	5.7	6.1	5.7	5.6	6.7	8.0	8.2	8.2	8.2	8.0	9.0	8.3	7.0	b	6.0	c	c	c	4.0	4.0	5.0
	35	5.0	5.0	5.0	5.0	5.5	6.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	b	6.0	c	c	c	4.0	4.0	4.4
Yellow Bay	Air	18.3	16.8	20.0	23.9	18.3	20.5	11.0	20.0	21.0	9.5	13.0	7.0	1.0	b	2.0	c	-10.0	-7.8	14.0	14.0	17.0
	S[a]	15.0	16.7	20.0	18.3	17.8	20.0	18.0	19.0	19.0	12.5	12.5	8.0	6.5	b	6.0	c	0.0	0.0	2.9	6.0	13.3
	3	11.1	15.6	19.8	18.3	17.2	16.0	18.0	19.0	18.0	13.0	12.2	8.5	6.5	b	6.0	c	1.7	1.7	2.9	5.3	13.1
	10	8.3	10.0	18.0	16.7	16.1	11.1	11.7	13.0	18.0	13.0	12.2	8.5	7.0	b	6.0	c	2.8	2.8	3.0	5.0	9.5
	15	6.7	8.9	12.0	12.2	13.9	10.0	10.0	11.7	17.0	13.0	13.0	8.5	7.0	b	6.0	c	3.3	3.3	3.0	5.0	6.8
	20	6.1	7.8	9.0	9.8	9.4	9.4	9.0	10.0	12.2	13.0	13.0	8.5	7.5	b	6.0	c	3.3	3.3	3.8	5.0	5.3
	25	5.2	6.7	6.7	6.7	8.9	8.9	8.9	9.0	10.0	12.0	9.0	8.7	7.3	b	6.0	c	3.9	3.9	4.0	5.0	5.2
	30	5.2	6.1	6.7	6.7	8.3	8.3	8.0	9.0	9.0	9.0	9.0	8.7	7.3	b	6.0	c	4.0	4.0	4.0	4.0	5.2
	35	5.2	5.2	6.5	6.5	6.7	7.2	8.0	8.7	8.7	8.7	8.7	8.7	7.0	b	6.0	c	4.0	4.0	4.0	4.0	4.0

[a] Surface

[b] Lake was too rough

[c] Beginning of continued ice cover

[d] Too shallow

unknown but pronounced influence on concentration of solutes and development of algal populations.

The hydrography of the lake includes a highly irregular shore line with many inlets, islands and bays. The margins of several bays is shallow and marshy, hence the water is warmer and solutes are more highly concentrated. Thus some eutrophic features probably explain, at least in part, the development and/or occurrence of certain eutrophic floral elements in this semi-oligotrophic lake.

Still another important condition is that of pollution. In a relatively short inlet flowage an unusual amount of pollution occurs from several sewage treatment plants discharging into the Flathead River. In addition, communities, resort areas and private homes around the lake contribute pollution from septic tank drainage. There is a moderate amount of drainage from agricultural and cultivated lands. In all, concentrations of nutrients (nitrates, phosphates, chlorides, sulphates) are maintained at relatively high levels for a semi-oligotrophic lake (Tables 7, 8, 9).

Related to the above mentioned conditions is an algal flora which well might be classified as a Diatom-Cyanophyte, moderately hardwater type. But the cyanophyte element is not only lower in number of taxa but also more weakly developed than in lakes which fall within such a classification. The Bacillariophyceae, in contrast comprises the dominant flora at all times of the year, becoming especially abundant in numbers of individuals during the fall and winter phytoplankton peaks. There are 399 species and varieties of diatoms in 42 genera as compared with 40 species of blue-green algae in 26 genera. In contrast the Chlorophyta are much fewer in number of individuals, but show the largest number of genera (70) of any of the phyla in Flathead Lake plankton. In surface collections at the confluence of the Flathead River, for example, diatom counts (early June) showed 43,632 organisms per L. as compared with zero blue-green and zero green algae. A late September collection showed 8,228 diatoms per L. at the same station in contrast to a zero count for Cyanophyta and Chlorophyta. It may be significant, however, that at this station in September the green algae showed a count of 3,276 organisms per L. at 30 M (Tables 11, 12, 13).

The composition of the algal flora of Flathead Lake in number of species so far reported is Chlorophyta 102 species (17.5%); Cyanophyta 40 species (7%); Chrysophyceae 12 species (2.1%); Bacillariophyceae 399 species and varieties (69.8%); Pyrrhophyta 13 species (2.0%); Xanthophyceae 4 species and Euglenophyta 1 species; Cryptophyta 2 species. When the Nygaard ratio is applied to the percentages of species composition in Flathead Lake, the quotient index is well above 1.0, thus indicating a eutrophic character.

As mentioned previously, the Chrysophyta as a phylum (Diatoms and Chrysophyceae) constitute by far the dominant flora group (Table 11). In this respect the lake shows an oligotrophic character remindful of oligotrophic floras in Arctic lakes. Nine genera of diatoms comprise

Table 7. NITRATE NITROGEN IN THE PHOTOSYNTHETIC ZONE OF SELECTED STATIONS IN FLATHEAD LAKE
Monthly Averages
(mg/l)

Month	Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole
JUNE	0.165	0.155	0.10	0.145	0.10	0.10	0.065
JULY	0.09	0.12	0.185	0.10	0.90	0.106	0.016
AUG.	0.15	0.17	0.11	0.10	0.08	0.063	0.116
SEPT.	0.17	0.24	0.09	0.13	0.095	0.115	0.125
OCT.	0.12	0.25	0.13	0.15	0.13	0.09	0.14
NOV.	0.16	0.11	0 18	0.145	0.135	0.115	0.12
DEC.	0.16	0.10	0.13	0.15	0.2	0.13	0.03
JAN.	--	--	--	--	--	--	--
FEB.	--	--	--	--	--	--	--
MAR.	--	--	--	0.20	0.17	0.18	--
APR.	0.23	0.3	0.24	0.18	0.28	0.07	0.26
MAY	0.14	0.17	0.10	0.12	0.18	0.09	0.10

Table 8. ORTHO-PHOSPHATE AT SELECTED STATIONS IN FLATHEAD LAKE
(mg/l)

Month	Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole
JUNE	0.14	0.08	0.10	0.085	0.165	0.07	0.09
JULY	0.125	0.15	0.156	0.116	0.133	0.17	0.163
AUG.	0.14	0.153	0.05	0.05	0.106	0.83	0.03
SEPT.	0.10	0.065	0.08	0.05	0.086	0.07	0.085
OCT.	0.15	0.17	0.06	0.05	0.08	0.08	0.16
NOV.	0.06	0.04	0.08	0.07	0.155	0.12	0.075
DEC.	0.11	0.14	0.04	0.04	0.10	0.11	0.10
JAN.	--	--	--	--	--	--	--
FEB.	--	--	--	0.08	0.12	0.13	--
MAR.	--	--	--	0.15	0.27	0.21	--
APR.	0.17	0.21	0.14	0.16	0.26	0.16	0.16
MAY	0.2	0.12	0.11	0.09	0.20	0.14	0.21

Table 9. TOTAL HARDNESS IN THE PHOTOSYNTHETIC ZONE AT SELECTED STATIONS IN FLATHEAD LAKE
Monthly Averages
(mg/l)

Month	Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole
JUNE	81.0	73.0	78.0	73.5	74.0	77.0	80.0
JULY	76.0	66.33	78.6	74.6	72.6	75.3	76.6
AUG.	76.0	74.0	78.0	79.3	75.3	77.3	74.6
SEPT.	77.0	78.0	88.0	81.0	84.0	85.0	79.0
OCT.	80.0	96.0	88.0	82.0	82.0	80.0	84.0
NOV.	91.0	87.0	94.0	92.0	91.0	92.0	93.0
DEC.	78.0	80.0	90.0	88.0	89.0	86.0	88.0
JAN.	--	--	--	--	--	--	--
FEB.	--	--	--	82.0	88.0	90.0	--
MAR.	--	--	--	78.0	78.0	92.0	--
APR.	78.0	90.0	76.0	84.0	80.0	88.0	82.0
MAY	90.0	88.0	90.0	84.0	82.0	88.0	80.0

the majority of the group and these are found in large numbers in mid-winter appearing more abundantly at 20 or 30 M than in the photosynthetic zone. Repeated sampling shows populations of all algal groups is generally greater in late summer and early fall (September readings, Table 12). The unusual large numbers of individuals at 20 or 30 M as compared with the surface and photosynthetic zone are considered to be related to the peculiar currents through Flathead Lake.

It is needed to be learned how much and how many of the algal components are developed within the lake, and how much of the flora represents transients contributed by inlet streams. When numbers of species carried into the lake by the Swan River are compared with numbers at Mid-Lake (for example) it is seen that the river count is significant (Table 11). It is suggested that many elements of the Chlorophyta, especially desmids, are 1) transients, or 2) drifters from back waters and shallow, marshy areas which are conducive to the multiplication of soft-water or acid-loving species. It is noteworthy that there is such a nearly uniform horizontal distribution of phytoplankton, quantitatively and qualitatively. The charts show these numbers in selected stations at three times of the year (June, September, December).

Nitrates and ortho-phosphates (Tables 7, 8) are relatively low as would be expected. But it is significant that these critical nutrient substances are high enough to support a much richer algal flora, and even algal blooms. That blooms do not occur is explained by the oligotrophic features such as 1) low temperatures, 2) low concentrations of organic acids and vitamins. That the lake is gradually (perhaps too rapidly) undergoing eutrophication is indicated by the development of slight blue-green algal blooms during the past 20 years of observation. In August there appears a profuse growth of Anabaena flos-aquae, a reliable indicator of eutrophication (and/or pollution), at least when this species appears in combination with certain other cyanophytes such as Aphanizomenon flos-aquae. This suggests that in Yellow Bay, Hell-Roaring Bay, and others the higher temperatures of shallow water combined with a higher concentration of nutrients (possibly from pollution) are sufficiently greater than in the years previous to 1950 to permit cyanophyte blooms to develop. These blooms are accompanied by peak numbers of Ceratium hirundinella and Dinobryon spp. It is significant that there are records of other cyanophyte species which are notable indices of eutrophy but their numbers are scant and there has been no tendency to form objectionable blooms. The evidences of eutrophy are clear enough that 1) monitoring of the algal flora is warranted, and 2) studies relating to pollution sources are needed for remedial practices.

Table 10. pH IN THE PHOTOSYNTHETIC ZONE OF SELECTED STATIONS
FLATHEAD LAKE
Monthly Averages

Month	Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole
JUNE	8.35	8.65	8.55	8.45	8.45	8.55	8.65
JULY	8.5	8.0	8.4	8.46	8.54	8.55	8.65
AUG.	8.5	8.5	8.5	8.55	8.5	8.54	8.53
SEPT.	8.6	8.45	8.55	8.55	8.55	8.6	8.55
OCT.	8.4	8.5	8.4	8.5	8.5	8.5	8.5
NOV.	7.45	8.35	8.25	8.4	8.35	8.45	8.4
DEC.	8.3	8.3	8.3	8.3	8.4	8.3	8.3
JAN.	--	--	--	8.3	8.3	--	--
FEB.	--	--	--	8.4	8.3	8.3	--
MAR.	--	--	--	8.6	8.4	8.4	--
APR.	8.3	8.4	8.5	8.4	8.4	8.4	8.4
MAY	8.3	8.5	8.6	--	--	8.5	8.3

Table 11. PLANKTON COUNTS AT SELECTED STATIONS IN FLATHEAD LAKE
EARLY JUNE
(no/l)

		Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole	Swan River
DIATOMS	S	43,632	97,440	30,548	101,548	71,808	125,280	69,364	41,994
	30M	92,920	99,544	87,000	66,120	111,360	205,314	133,446	44,436-3M
CHRYSOPHYCEAE	S	5,220	56,616	26,100	8,700	5,220	71,340	14,856	468
	30M	15,324	39,820	12,180	5,220	10,440	40,026	22,620	1,740-3m
PYRRHOPHYTA	S	--	468	--	--	468	--	--	936
	30M	--	--	--	--	--	--	--	--
CHLOROPHYTA	S	--	468	--	--	1,740	--	936	--
	30M	--	--	6,960	--	--	3,480	--	468-3M
CYANOPHYTA	S	--	--	--	--	--	--	--	--
	30M	--	--	--	--	--	--	--	--

Table 12. PLANKTON COUNTS AT SELECTED STATIONS IN FLATHEAD LAKE
SEPTEMBER 21
(no/l)

		Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole	Swan River
DIATOMS	S	8,228	51,028	21,924	42,272	21,916	35,064	18,680	60,664
	30M	50,602	49,188	88,440	52,200	33,996	60,588	22,854	50,392-3M
			4 M						
CHRYSOPHYCEAE	S	4,316	14,288	5,220	12,180	13,920	10,440	3,948	5,220
	30M	--	5,220	10,440	--	468	5,220	8,700	--
PYRRHOPHYTA	S	468	1,740	6,960	5,220	6,960	468	10,908	468
	30M	936	1,740	--	1,740	3,480	10,440	--	5,220
CHLOROPHYTA	S	--	6,960	3,168	2,208	2,076	2,208	1,740	3,612
	30M	3,276	936	5,520	1,740	2,208	1,740	468	--
CYANOPHYTA	S	--	1,740	3,948	--	3,480	936	5,140	--
	30M	--	3,480	--	--	2,808	6,960	936	--

Table 13. PLANKTON COUNTS AT SELECTED STATIONS IN FLATHEAD LAKE
DECEMBER
(no/l)

		Flathead R. Confluence	Swan R. Confluence	Mid Lake	Yenne Point	Yellow Bay	Woods Bay	Deep Hole	Swan River
DIATOMS	S	47,112	909,620	36,204	29,580	39,684	57,552	19,272	117,048
	30M	30,180	78,900	54,244	28,776	6,204	27,082	46,980	155,576-3M
CHRYSOPHYCEAE	S	6,960	1,740	1,740	8,700	3,948	3,480	936	3,480
	30M	5,220	2,208	2,406	--	2,208	2,208	1,740	1,740-3M
			4 M						
PYRRHOPHYTA	S	--	--	--	--	--	--	--	--
	30M	1,740	468	--	--	--	468	--	1,740-3M
CHLOROPHYTA	S	3,480	--	--	5,220	1,740	1,740	--	3,948
	30M	3,480	1,740	1,740	--	--	1,740	--	--
CYANOPHYTA	S	468	--	--	--	--	--	--	--
	30M	--	--	468	--	--	--	2,208	--

SECTION XI

HIGHER AQUATIC PLANTS IN FLATHEAD LAKE

Higher plants (water weeds) play an important role in aquatic environments inasmuch as they: 1) are involved in fish biology (food and shelter), as well as for other animals (birds and mammals); 2) provide a habitat and support many kinds of fish-food organisms; 3) influence water chemistry and the composition of solutes; 4) are factors in aging of lakes, leading to eutrophication; 5) often interfere with recreation uses and 6) spoil domestic water supplies.

Because of its hydrography and morphometry (mostly oligotrophic) Flathead Lake does not provide suitable substrates for a conspicuous flora at this time. But there are a few sectors where aquatic plants show an increasing amount of limnological concern. It is planned that a complete inventory of aquatic plants in Flathead Lake will be taken, with qualitative and quantitative mapping of certain sectors. It is appropriate to monitor the development of weed beds because of the several relationships mentioned above. Whereas no complete survey of the lake has been undertaken to date, exploratory samplings permit a tentative listing and an appreciation of what the vegetation is doing for and to the lake. This is particularly true for some bays and shallows where nutrient-bearing sediments provide a suitable substrate.

In the zones lateral to the delta area where the Flathead River enters the lake, there is a normal build-up of sedimentary reefs quite unlike the rocky shores which characterize most of the lake. Accordingly, the flat margins and the shallow water in the north part of the lake permit the development of an aquatic flora. It can be predicted that the indefinite lake margin on the north shore will be extended and built up by encroaching semi-aquatic plants, expanding the marsh lands lakeward.

In Hell Roaring Bay (a lobe of the Polson Bay sector in the south sector of the lake) occurs an example of the ability of aquatic plants to contribute to the aging of a lake. The lake in the southern part is relatively very shallow in any event; the margins are low and marshy, being formed by debris and outwash from the lateral and terminal morains which bound the lake on the south. Lake currents, wind action, and the configuration of the shore line combine to produce deep sediments and flat beaches. During the past 25 years the lakeward extension of the marshes by aquatic and marginal plants has been observable along the north and south shores of Hell Roaring Bay. Also as a result of wind and wave action and peculiar currents, a reef has been formed on the north side of the bay which has resulted in a large lagoon. Here aquatic plants have a suitable basin for profuse growth and their 'fill-in' activity is very obvious. It is a truism that the aging of a lake proceeds logarithmically under the influence of aquatic plants. For as sediments accumulate, more and more favorable substrates are formed for

aquatics; the more profuse the aquatic plants, the greater and the more rapid the accumulation of organic, fertilizing debris that supports greater plant productivity.

The reef that has produced the lagoon is populated with several species of Salix that have recently migrated there, also Cornus stolonifera, and other shrubs. The soil is under bind with Equisetum spp. and a variety of terrestrial and semi-aquatic phanerogams.

On the north shore of Hell Roaring Bay is a migrating marsh composed of Typha latifolia, Scirpus validus and several species of Carex. The lake margin and the lagoon have become gardens of Polygonum natans, P. coccineum, Elodea occidentalis, Potamogeton pusillus, Potamogeton natans, Hypericum sp., Ceratophyllum demersum and Myriophyllum exalbescens.

The south shore is invaded by a dense stand of Typha and Scirpus, intermingled with Acorus calamus and semi-aquatic species of Carex, Eleocharis and Juncus. Very sparse and rarely found are plants of Indian Rice, Zizania aquatica, apparently the remains of plantings attempted by sportsmen to introduce duck-food plants. Butomus umbellatus along the north shore of the lake in the delta region is another such introduced plant.

The fluctuating level of the water in Flathead Lake (because of impoundment operations) is a decided determiner of the kind, amount and limnological aspects of aquatic vegetation. The rather unique situation presents some biological problems which invite surveys and monitoring.

Table 14. TENTATIVE CHECK LIST OF AQUATIC AND MARGINAL PLANTS IN FLATHEAD LAKE

Typhaceae

Typha latifolia (L.)

Sparganiaceae

Sparganium chlorocarpum Rydb.

Najadaceae

Najas flexilis (Willd.)
Potamogeton gramineus (L.)
Potamogeton natans (L.)
Potamogeton pectinatus (L.)
Potamogeton pusillus (L.)

Alismaceae

Alisma plantago-aquatica (L.)
Sagittaria latifolia (Willd.)

Hydrocharitaceae

Anacharis occidentalis (Pursh.) Victoria

Butomaceae

Butomus umbellatus (L.)

Gramineae

Beckmania syzigachis (Steud.) Fernald
Glyceria fluitans (L.) R. Br.
Glyceria grandis Wats.
Zizania aquatica (L.)

Cyperaceae

Carex lacustris Willd.
Carex rostrata Stokes
Carex stipata Muhl.
Carex vulpinoidea Michx.
Eleocharis tenuis (Willd.) Schultes
Eleocharis parvula (R. & S.) Link.
Scirpus acutus Muhl.
Scirpus validus (Vahl.)

Araceae

Acorus calamus (L.)

Lemnaceae

Lemna minor (L.)
Lemna trisulca (L.)
Spirodela polyrhiza (L.) Schleid

Table 14 (continued). TENTATIVE CHECK LIST OF AQUATIC AND MARGINAL PLANTS IN FLATHEAD LAKE

Juncaceae
Juncus balticus (Willd.)
Juncus militaris Bigel.

Iridaceae
Iris pseudacorus L.

Salicaceae
Salix longifolia Muhl.
Salix serissima (Bailey) Fernald
Salix amygdaloides Anders

Betulaceae
Alnus sinuata ?

Polygonaceae
Polygonum coccineum Muhl.
Polygonum hydropiperoides Michx.
Polygonum natans Eaton
Polygonum persicaria (L.)

Ceratophyllaceae
Ceratophyllum demersum L.

Ranunculaceae
Ranunculus septentrionalis Poir.
Ranunculus trichophyllus Chaix.

Cruciferae
Rorippa palustris (L.) Bess

Callitrichaceae
Callitriche palustris L.

Hypericaceae
Hypericum ellipticum f. *aquaticum* ?. Fassett

Haloragidaceae
Myriophyllum exalbescens Fernald

Umbelliferae
Sium suave Walt.

Cornaceae
Cornus stolonifera Michx.

Primulaceae
Lysimachia thyrsiflora L.

Labiatae
Scutellaria epilobiifolia Hamilton

Solanaceae
Solanum dulcamara L.

SECTION XII

ROTIFER AND CRUSTACEAN PLANKTON COMMUNITIES OF FLATHEAD LAKE

The zooplankton fauna of Flathead Lake has been surveyed several times since Forbes made his preliminary investigations in 1891. The reports of Elrod, [40,41], Young, [9], and Bjork, [13] demonstrated the dynamic nature of the Flathead fauna since Forbes' collection. The Montana Fish and Game Department has taken a number of surface samples of zooplankton at all seasons of the year since 1967 in connection with their fisheries investigations. Potter and Tibbs since 1971 have been studying the systematics, distribution, and ecology of zooplankton in the lake. The objectives of their study have been to determine the diel and other temporal variations of density and spatial distribution of zooplankton as influenced by physical and chemical features of the lake. Their work has been closely coordinated with that of Hanzel of the Fish and Game Department and with Ivory in Polson Bay.

METHODS

Zooplankton samples were collected in the field with several types of sampling gear. A Clarke-Bumpus plankton sampler was used to obtain several series of horizontal collections. More numerous collections were taken with a large, metered net towed near the surface. Such surface collections were taken at all seasons and dates through the year 1967-1972 (Hanzel, Montana Fish and Game Department).

Vertical collections were taken by Potter through five meter intervals with Wisconsin nets and Wisconsin closing nets. These net hauls were usually through five meter intervals in the water column. Sample collections were preserved immediately in the field or returned to the laboratory for fixation or preliminary observation. Aliquot portions of each sample were studied under a dissecting scope after specific determinations had been completed at higher magnification.

Quantitative analysis of one milliliter aliquot portions was attempted only on the Clarke-Bumpus collections and vertical Wisconsin net collections. Because these samples constituted the minority of material, the information presented below indicates relative rather than absolute abundance of any species.

Vertical temperature profiles were taken with a Foxboro portable thermocouple and light extinction curves were taken with a Gemware Submarine Photometer. Several temperature profiles were obtained from the Montana Fish and Game Department.

Chemical analyses were not conducted regularly because Morgan demonstrated the relatively stable chemical composition of lake water. The few tests routinely conducted by the Fish and Game Department indicated

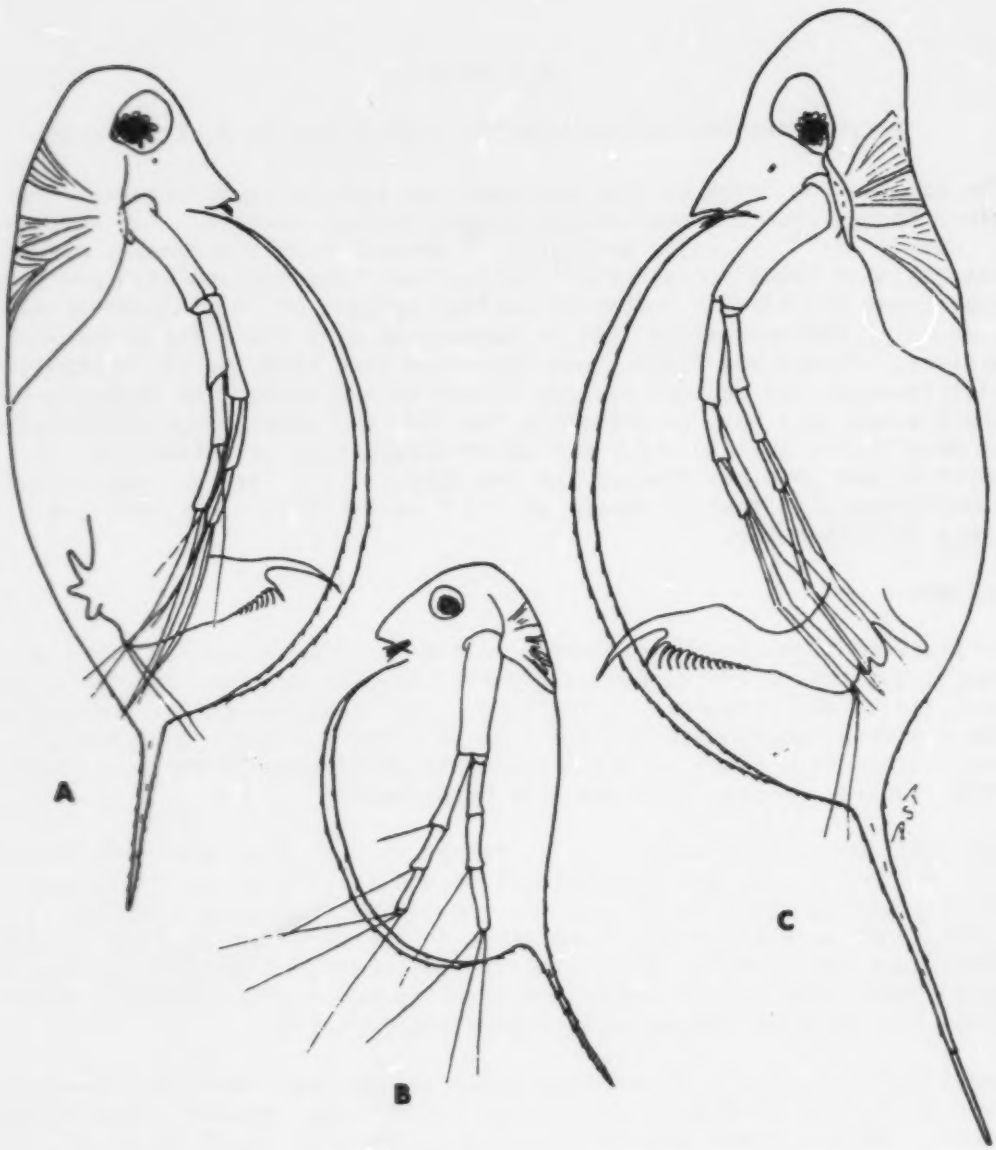

Figure 5. Daphnia in lake.
A. Daphnia rosea, mature female, Yellow Bay, 2 February, 1971; B. Daphnia longiremis, mature female, Yellow Bay, 30 January, 1971; C. Daphnia thorata, mature female, Woods Bay, 21 July, 1969.

the continuing stability of lake water chemistry.

RESULTS

A preliminary list of the Flathead Lake zooplankton appears in Table 15. The table also presents the depth distribution of each species and temporal occurrence. Abundance is relative as compared to other species with consideration allowed for unusual temporal abundance of the more common forms.

The more common forms of zooplankton found in Flathead Lake, Daphnia spp., Kellicottia longispina, Keratella cochlearis, Cyclops bicuspidatus thomasi, and Diaptomus ashlandi, compose a community similar to that described by Scheffer and Robinson,[42] for Lake Washington. These forms occur commonly across the lake; the less common forms display more specific preference for depth, temperature, and other factors associated with open lake or bay environments.

The three species of Daphnia -- D. thorata, D. longiremis, and D. rosea -- are of particular interest because temporal and spatial distribution seem to be influenced primarily by temperature (Figure 5). Neither Daphnia longiremis nor Daphnia rosea have been reported from the lake though Bjork (1965, personal communication) mistakenly reported D. longiremis to be D. longispina. We have not yet determined whether these species have always been present or are recently introduced. Neither species has been observed in the few recovered samples from collections by Forbes and Elrod.

Daphnia longiremis is noted by Brooks,[43] to be a cold stenotherm. This species does maintain an association with cold waters of Flathead Lake and exhibits peak populations during late winter. At that season D. longiremis is the most abundant cladoceran in the lake and occurs from the surface to depths of 50 meters. During summer and fall months when the lake is stratified with warm surface temperatures D. longiremis restricts itself to hypolimnetic depths. At that time it is common, but it is not nearly as abundant as during winter months.

Daphnia rosea is the least abundant of the three species. It occurs at all depths at all seasons with modest populations developing in spring. Daphnia rosea has not previously been reported from the lake. It may have been present earlier though not recognized as distinct from the other species. It may be a recent introduction from other Flathead Valley ponds where it is often abundant.

The most interesting temporal sequence is demonstrated by Daphnia thorata. Early exephippial females appear in the plankton as water temperatures reach five to seven degrees centigrade during April and May. These early individuals appear in shallow bays and near shore. The populations increase gradually through the summer. Daphnia thorata replaces D. longiremis in surface waters as summer stratification develops.

Table 15. PRELIMINARY SEASONAL AND DEPTH DISTRIBUTIONS FOR ROTIFERA AND CRUSTACEA IN FLATHEAD LAKE, MONTANA

Organism	Depths	Seasons
ROTIFERA		
Asplanchna sp.	surface	1,2,3*,4
Brachionus sp. ?	surface	2
Chromogaster sp.	surface	2
Collotheca sp.	surface	2,3
Conochilus unicornis Rousselet	all depths	1*,2*,3,4
Dissotrocha sp. ?	surface	2
Euchlanis sp. ?	surface	1
Filinia longiseta (Ehrenberg)	mid, deep	1*,2,3,4*
Kellicottia longispina (Kellicott)	all depths	1*,2*,3*,4*
Keratella cochlearis (Gosse)	all depths	1*,2*,3*,4*
Keratella quadrata (Muller)	surface	1*,2,3,4
Ploesma sp.	surface	2
Polyarthra vulgaris Carlin	surface	1,2
Trichotria sp.	deep	1,4
Tylotrocha sp. ?	surface	1
CLADOCERA		
Acroperus harpae Baird	surface	2
Bosmina longirostris (O.F.Muller)	surface	1*,2,3,4
Chydorus sphaericus (O.F.Muller)	surface	1,2,3,4
Daphnia longiremis Sars	all depths	1*,4
	deep	2,3
Daphnia rosea Sars	all depths	1,2,3,4
Daphnia thorata Forbes	surface	1,2*,3*,4
Eubosmina sp.	surface	1,2*,3,4
Eurycercus lamellatus (O.F.Muller)	surface	1,2,3,4
Leptodora kindtii (Focke)	deep, surface at night	2*,3
Scapholeberis kingi Sars	surface	1,2,3*,4
Sida crystallina O.F.Muller	mid	2
COPEPODA		
Cyclops bicuspidatus thomasi S.A. Forbes	all depths	1*,2*,3*,4*
Diaptomus ashlandi Marsh	surface, mid	1*,2*,3*,4*
Diaptomus leptopus S.A.Forbes	surface	2
Epischura nevadensis Lilljeborg	surface, mid	1,2,3
Eucyclops agilis (Koch)	surface	2
Ergasilus sp.	deep	1,4
Salmincola sp.	on fishes	1,2,3,4

1, spring; 2, summer; 3, autumn; 4, winter; *, abundant

surface - epilimnion mid - metalimnion deep - hypolimnion

Highest densities occur in October and November when males appear in the population. Sexual reproduction with the formation of ephippia persists through early February, but populations begin to decline with cooling water temperatures of mid-November. Between late February and April D. thorata is absent from the Flathead Lake plankton community.

These three species are much used as food by pygmy whitefish (Prosopium coulteri, Eigenmann,[48]) and landlocked silver salmon or kokanee (Oncorhynchus nerka Waldbaum) (Hanzel,[24]). Possibly predation is an important influence on population size and particularly when females carry ephippia and are most visible.

Other species important in fish diets are Leptodora kindtii and Epischura nevadensis. Both are summer forms that display temporal periodicity similar to Daphnia thorata. The seasonal occurrence of L. kindtii in Flathead is supported by observations of Chambers, Burbidge, and Van Engel,[44] who noted the species to be present only at temperatures near and above ten degrees centigrade.

Leptodora displays distinct diel migrations. Individuals disperse between five and thirty meters depth during the day and congregate in the top ten meters of water during the night hours. Day distribution seems to be at depth with light below twenty foot candles, yet the few individuals that occur near the surface indicate that light may be only one influential factor.

Epischura is a form commonly eaten by planktivore fishes, yet it is much less common in the plankton than the cladocerans mentioned above. Importance as a food organism as compared to uncommon occurrence in the plankton probably reflects selectivity of fish predators (Brooks,[43]).

DISCUSSION

These few species displayed distinct periodicities in their occurrence and seemed to be controlled by environmental factors. The perennial species may be more tolerant of seasonal fluctuations or may display similar population variations that will become evident when quantitative analyses are completed.

Description of the modern plankton community and its comparison to earlier investigations has indicated a few changes of community structure that may have been influenced by accelerated eutrophication, fish introduction, and other factors. We conclude that our efforts can profitably continue with a comparison between present conditions and previous collections and accounts. Analysis of sediment cores for plankton microfossils (Deevey,[46]) will be completed as another comparator.

SECTION XIII

FISH POPULATION OF FLATHEAD LAKE

Flathead Lake is the state's largest and one of its most important sport fishing lakes. The lake historically has been an important physical feature of the area but very little information was written about the fisheries of the lake prior to 1900. The available data are general notes on specific fish as they were recorded by early investigators as Evermann,[47]; Eigenmann,[48]; Gilbert and Evermann,[49], and Evermann and Smith,[50]. In 1906, Henshall published a list of the fishes of the state but his list was incomplete due to limited records in the western areas. The first real fishery studies were initiated in 1916 by Elrod, et al.[51]. Their investigation provided the basis for describing the fish present, their relative abundance and some historical notes on the introduction of exotic fish. Elrod described nine of the ten native fish species, only missing the small inconspicuous pygmy whitefish (Table 16).

First fish management efforts on the lake, other than the harvesting of fish by fishermen, occurred before the turn of the century with the introduction of largemouth bass in 1898. Early concern to replenish the stocks of fish in the lake by the local citizens was exhibited in their action when they petitioned the State Government to build a fish hatchery at Somers. Fish plants and other information prior to the completion of the Somers Hatchery were often incomplete or lacking in lieu of records kept by the individual sportsman. Between 1905 and 1916, most of the fish introductions made into this lake occurred; during this interval thirteen exotic fish species were planted (Table 16). Since that time, only two species of Pacific salmon have been added; the kokanee and coho salmon. Five of these exotic species did not survive in the lake; they were the small-mouth bass, white crappie, grayling, chinook and coho salmon. The other species continue to live and reproduce their kinds with varying degrees of success in this lake system.

Elrod, et al.[51] described the blue-gill, a member of the sunfish family, as being introduced into the lake in 1910 but it is believed that the fish introduced was the pumpkinseed. No positive records of blue-gill have since been found in the valley. All areas described for this fish species are and have been occupied by the pumpkinseed. The only other questionable species introduced in the lake was noted in the salmon plant of 1916. To date, it is not known what species of salmon was planted.

Weisel,[52] in his "Fish Guide for Intermountain Montana" and more recent Brown,[53] with his "Fishes of Montana" described in detail the species of fish present in this lake and drainage area.

Early investigators found fish life in Flathead Lake to be quite scant so their efforts were directed toward the establishment of other fish species that might provide a commercial fishery. The maximum effort was

Table 16. NATIVE AND EXOTIC FISH SPECIES IN FLATHEAD LAKE

Species[a]	Native or year of introduction	Game - Nongame Classification	Reference source
Cutthroat	Native	Game	Elrod, 1929
Mountain whitefish	Native	Game	Elrod, 1929
Pygmy whitefish	Native	Game	Hanzel, 1969
Dolly Varden	Native	Game	Elrod, 1929
Northern squawfish	Native	Nongame	Elrod, 1929
Peamouth	Native	Nongame	Elrod, 1929
Longnose sucker	Native	Nongame	Elrod, 1929
Largescale sucker	Native	Nongame	Elrod, 1929
Redside shiner	Native	Nongame	Elrod, 1929
Slimy sculpin	Native	Nongame	Elrod, 1929
Largemouth bass	1898	Game	Biennial Report,1913-14
Lake trout	1905	Game	Biennial Report,1905-06
Lake whitefish	1909	Game	Biennial Report,1909-10
Pumpkinseed	1910	Nongame	Elrod, 1929
White crappie	1910	Nongame	Elrod, 1929
Smallmouth bass	1910	Game	Elrod, 1929
Black bullhead	1910	Nongame	Elrod, 1929
Yellow perch	1910[b]	Nongame	Fish & Game Records
Brook trout	1912	Game	Biennial Report,1911-12
Cutthroat trout	1913	Game	Biennial Report,1913-14
Grayling	1913	Game	Biennial Report,1913-14
Rainbow trout	1914[c]	Game	Elrod, 1929
Salmon[d]	1916	Game	Biennial Report,1917-18
Kokanee	1935	Game	Fish & Game Hatchery Records (Polson)
Silver (Coho)	1969	Game	Fish & Game Hatchery Records (Anaconda)

[a] Common names of fishes in this report are those given in American Fisheries Society, 1970. A list of common and scientific names of fishes from the United States and Canada. Spec. Pub. No. 6, Third Edition, 150 pp.

[b] Introduction of this species not recorded but it was apparently included in the mass introduction of warm-water fish during 1910.

[c] Year of first recorded plant; possible introduction as early as 1900.

[d] This species purchased as Chinook or Quannat salmon from Oregon; survival reports from this plant indicate it included the Chinook salmon, silver and kokanee. Apparently there was a mixture of eggs or questionable identification.

spent over a six-year period when 8 million lake whitefish fry were introduced. The lake trout were introduced during the same period but were considered a companion species that might provide a large sports food fish. The first commercial netting program was attempted during the fall of 1913 but yielded only Dolly Varden. The 1913-1914 "Montana Biennial Report" describes the sale of thousands of pounds of Dolly Varden on the Kalispell market for $.20 to $.25 per pound. Another attempt at fishing commercially was tried in the fall of 1925, but was utter failure.

In 1907, a water development project was completed that undoubtedly had a detrimental effect on the lake fishery. This power diversion dam on the Swan River blocked spawning runs from one of the two major inlet streams of Flathead Lake. These two streams provided the only spawning areas for the Dolly Varden and cutthroat trout.

Another hatchery was built on the east shore of the lake in 1928 at Station Creek, but was closed in 1959. Station Creek waters were too cool to hatch and rear fish economically.

The first sport fishery for kokanee in the lake was noted in 1933 when numerous salmon were creeled during the summer fishery. That fall large numbers of salmon were found congregating along the shoreline. These spawning populations were collected and canned in Polson with over 21,000 cans being distributed throughout Montana by the Relief Commission.

The second major water development project that directly affected the fishes of the lake was the completion of Kerr Dam in 1938 at the outlet of the lake. Although this structure did not block any fish migrations, it did have an effect on the fish populations by the artificial manipulation of the lake level. In an agreement between the federal, state, and private principals, the lake levels are regulated to follow an annual draw-down of ten feet. The maximum draw-down of the lake that is allowable by the present physical features of the outlet would be an additional six feet. Structures of this type that impound water on existing deep water lakes have seldom had any beneficial effect on the fish species or the lake habitat.

Events relating to the fisheries of the lake during the war years of the Forties were limited to the annual planting of salmon and trout and a controversy over a water development proposal by the Corps of Engineers. Bitter debate arose over the plan to raise the level of Flathead Lake some 37 feet over the existing full pool level. This rise in water would have placed the lakeshore at Kalispell and flooded most of the productive land of the valley floor. This grandiose plan was shelved and replaced by an alternate proposal for a multi-purpose flood and power dam on one of the three major tributaries of the Flathead River. Hungry Horse Dam was located on the South Fork of the Flathead River and completed in 1953. The 564-foot high dam blocked fish movements from Flathead Lake and lost over 60 percent of the spawning areas that provide the annual recruitment of trout to the lake. Water discharges from the dam have also altered the aquatic habitat in the lower 50 miles of the Flathead

River.

The first fisheries biologist for the Montana Fish and Game Department was assigned to the area in 1949. His initial duties were to assess and inventory existing fisheries resources, of which Flathead Lake is an important part (Stefanich,[54-58]). Assisting in this monumental job was the fisheries work directed through the University of Montana and its Biological Station located at Yellow Bay. Work on the lake included the reports on growth of the kokanee by Brunson, Castle and Pirtle,[59], fall sampling of cutthroat trout by Brunson, Pennington and Bjorklund,[60], and life history aspects of the lake whitefish by Bjorklund,[61], and Brunson and Newman,[62].

In 1955, a large white sturgeon was reported to have been caught in Flathead Lake (Brunson and Block, [63]). The catch climaxed the mystery surrounding various reports of "monsters" being seen in the lake. There is considerable question as to the origin of this fish which was reportedly caught on May 28, 1955. This sturgeon measured 92 inches long and weighed 181 pounds and 1 ounce. Accounts of such sighting of large objects has decreased but still are being reported.

The initial work during the 1950's established the need for further detailed work in defining the role and importance of the tributaries above Flathead Lake. The detailed work began in 1955 on the remaining 180 miles of free-flowing river system above the lake. The principal investigators were Stefanich and Block,[56]; Block,[64]; Stefanich,[65-68]; Johnson,[69,70]; Rahrer,[71], and Hanzel,[15-18]. Their work defined the spawning movements of the Dolly Varden and cutthroat trout in the Flathead River system above the lake.

They established that after hatching, cutthroat trout remain two years in the lower 50 miles of the North and Middle Forks of the Flathead River. During their third summer, they make a mass downstream migration. While on the downstream journey, these fish concentrate in the larger, deep pool areas of the lower 20 miles of the river above the lake. The time taken by these fish to descend from these rivers varies from two weeks to two months. During this period they move 50 to 80 miles. From late fall through the winter months descending cutthroat reach and enter the lake. They remain here until they reach maturity which is generally after one and one-half years in the lake.

The predominance of immature fish in the Forks of the Flathead River is evidenced by the average sizes of cutthroat trout measured in creel census records taken on the North Fork. In 1955, Block stated the average total length was 8.5 inches. Eight and nine years later (1961 and 1962), the sizes were 8.4 and 8.5 respectively.

Data from the extreme upper river areas indicate a year-around resident cutthroat population. These mature cutthroat appear to be the non-migratory type for fish tagged in the upper reaches have been recaptured within five miles of the release point during three consecutive years.

The recapture data also indicate a portion of the cutthroat trout population in the North and Middle Fork Rivers are attracted to many of the waters draining Glacier National Park. Fish tagged and released in these rivers have been recovered in Kintla, Bowman, and McDonald Lake. This is an upstream movement of 10 to 20 miles.

After the migrating type of cutthroat trout enter Flathead Lake, they disperse along the entire shoreline and occupy an area near the surface. An apparent winter concentration (November-December) occurs in the lake near Dayton, Montana (Big Arm Bay-north of Wildhorse Island). With a life expectancy of six years, cutthroat trout cannot be expected to make more than two spawning runs into the upper river spawning areas during their lifetime.

There is an apparent escapement of cutthroat trout to the lower Flathead River below Kerr Dam. Fish tagged in Flathead River above Flathead Lake have descended the river into the lake, passed through the lake and have been caught below Kerr Dam.

Studies of movements of the Dolly Varden have been considered on mature fish only. All the data exemplify an inter-dependent relationship between the lake and river system. Four of the total thirteen recaptures from the Middle Fork Tagging Site (Bear Creek weir-99 miles above the lake) were caught in the lake. Fourteen of the total twenty-eight recaptures from the North Fork Tagging Site (Trail Creek weir-105 miles above the lake) were caught in the lake. Nine of the total fifty-five returns from fish released in Flathead Lake were caught upstream on their spawning run. Two of the lake-tagged fish were recaptured above the weir sites on the Middle and North Fork Rivers. Movements within the lake show constant traveling along the entire shoreline except during the spring, when concentrations occur near the mouths of the Flathead and Swan Rivers.

The Flathead Lake Fishery is dependent on the natural reproduction in the lake and recruitment from the tributary system above the lake. The lake and stream work defined the relationship of the lake as an integral part of this lake-river system, each part being dependent upon the other to provide the necessary environment for the production of the dominant game fish. These species are the cutthroat trout, Dolly Varden, kokanee, lake trout, mountain whitefish and lake whitefish. Since 1953, fisheries management efforts and recommendations for Flathead Lake and the river system above the lake have been directed toward principles that will maintain and preserve the interdependent relationship of this lake-river system.

Fishing pressure on Flathead Lake was measured by Robbins,[72] and his estimates of 129,000 man days per year expresses the use of 1.03 man days per acre per year. Nonresident fishermen represent nearly 25 percent of the total fishing pressure. Catch rates varied with species and by season. Creel composition for the entire year was 75 percent kokanee, 15 percent yellow perch, 3 percent cutthroat trout, 3 percent Dolly

Varden and the remaining portion an aggregate of lake trout, largemouth bass and mountain whitefish.

This lake-river system is located in an area that is rapidly developing its natural resources; water, timber, and recreation. During the development, it is very critical that further assessments be made on the fishery of this river system as they would be affected by proposed water development projects.

The Montana Fish and Game Department in 1966 initiated a special fisheries study to determine fish population trends, life histories, and seasonal fish distribution of the Flathead Lake system. Through the use of specialized gear, the horizontal and vertical distribution of the major fish species in Flathead Lake were established in twelve major fish use areas (Hanzel,[19-24]). A major portion of all fish were collected during the summer seasons with the largest catches being taken in areas directly influenced by currents. Seasonal variation in species composition and length frequency distribution were determined for the twelve areas. These areas represent twenty-one sample stations in the lake.

A total of 8,912 fish were collected in 163 net sets during the fish sampling program on Flathead Lake, November 1967 through December 1970 (Table 17). The major fish species listed in order of relative numbers were: lake whitefish, peamouth, kokanee, northern squawfish, Dolly Varden, yellow perch, pygmy whitefish, mountain whitefish, longnose sucker, large-scale sucker, lake trout, redside shiner, cutthroat trout, coho salmon and largemouth bass. Species composition of the total netting data represents the best year-around picture of the relative fish abundance found in Flathead Lake, Figure 6. Significant changes were found in species composition when comparing the deep (60 to 270 feet depth) netting series (Nov. 1967 - August 1969) to the shallow (6 to 60 feet depth) water netting series. Shallow water sampling yielded more than one and one-half times as many fish as the deep water sampling. Nongame fish made up most of the increase with their numbers gaining fourfold while the game fish numbers showed a slight drop (Table 17). The size range and maximum weight of the major fish species taken from the lake are present in Table 18.

Three main lake zones were used by the fish; near the bottom, near the surface, and the open pelagic waters. All species collected preferred a zone within 8 feet of the bottom, except the cutthroat trout and kokanee. Cutthroat trout showed a distinct preference for the area near the surface while the kokanee selected the open pelagic waters. The depth and spatial distribution of the kokanee were periodically checked with the use of a recording sonar. Light penetration, plankton concentration and water temperature were the three factors affecting the kokanee distribution. Variations of these factors continually altered the kokanee distribution.

Rough fish, such as northern squawfish, peamouth, longnose suckers and largescale sucker, preferred the shore areas that ranged in depth from

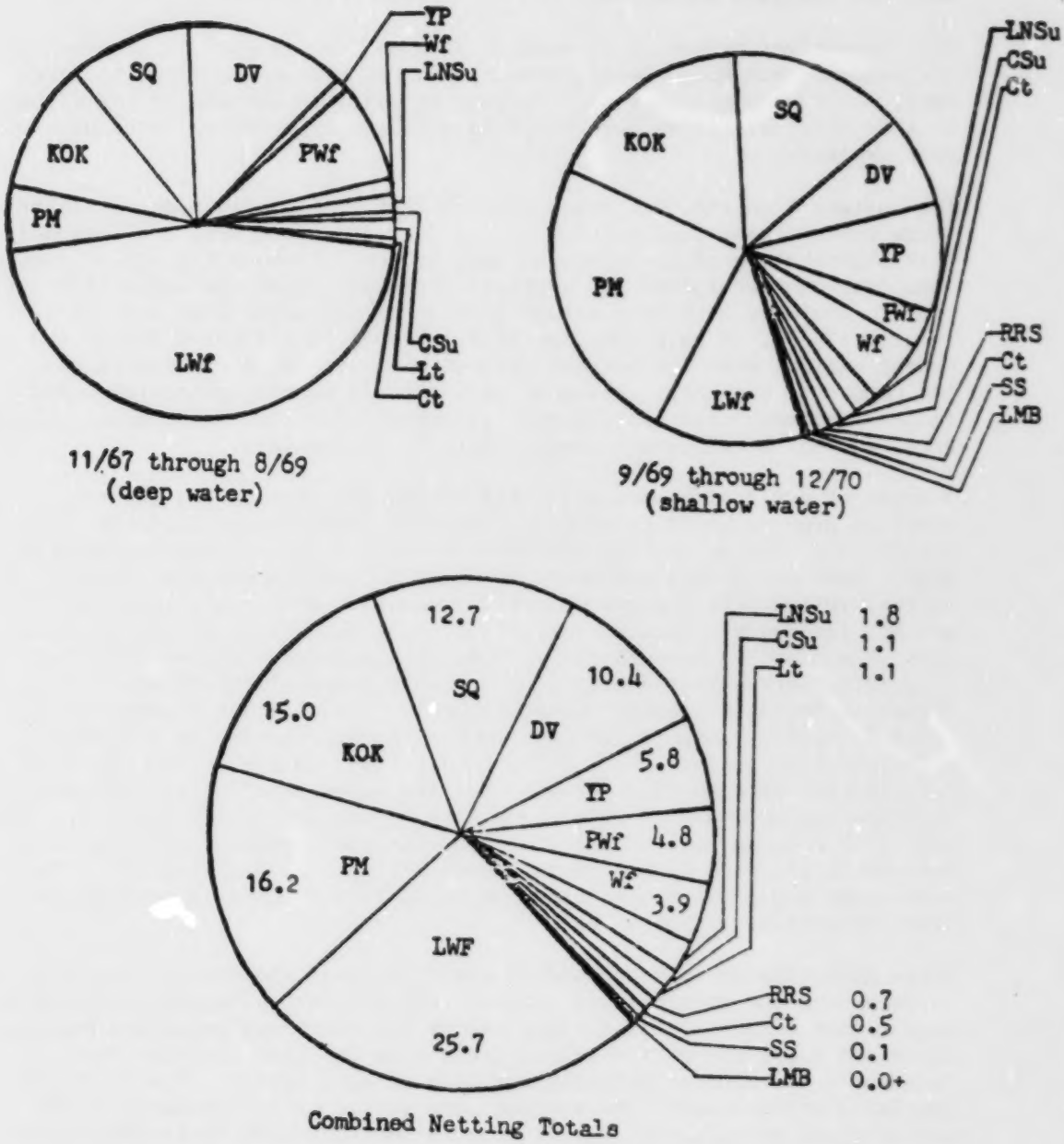

Figure 6 Species of fish netted in Flathead Lake.

Table 17. FISH SPECIES AND OTHER NETTING DATA FOR FLATHEAD LAKE, WINTER 1967 THROUGH FALL 1970
(species as percent of total sample size)

Fish Species	PERCENT SPECIES COMPOSITION										
	FIRST PERIOD November '67 - August '69				SECOND PERIOD September '69 - December '70				First Period Totals	Second Period Totals	Total Period
	Winter 1967	Spring 1968	Fall 1968	Summer 1969	Fall 1969	Winter 1970	Summer 1970	Fall 1970			
Lake whitefish	53.2	48.5	31.3	50.7	7.3	30.0	11.2	24.6	44.8	13.2	25.7
Peamouth	11.0	1.9	6.5	1.7	24.0	2.1	29.1	19.2	5.0	23.5	16.2
Kokanee	3.0	6.4	19.4	9.9	28.1	2.9	0.4	16.4	10.9	17.7	15.0
Northern squawfish	11.0	15.1	12.7	5.5	15.4	10.0	16.4	10.4	10.4	14.3	12.7
Dolly Varden	12.0	16.3	14.5	16.0	7.7	17.9	4.9	8.7	14.8	7.5	10.4
Yellow perch	0.6	0.2	2.2	0.3	2.3	0.7	31.2	1.0	1.0	8.9	5.8
Pygmy whitefish	3.0	4.2	8.7	11.3	0.9		0.9	9.3	7.7	3.0	4.8
Mountain whitefish	2.0	2.8	0.4	1.2	6.2	20.7	1.4	6.6	1.4	5.5	3.9
Longnose sucker	1.3	2.3	2.2	0.8	1.6	10.0	2.3	1.3	1.5	1.9	1.8
Largescale sucker	1.2	0.1	0.6	0.4	1.4	1.4	2.0	1.0	0.7	1.4	1.1
Lake trout	0.1	2.2	1.5	0.6	1.6		0.2	1.2	1.0	1.2	1.1
Redside shiner					2.5					1.2	0.7
Cutthroat trout	1.6			1.5	0.6	4.3		0.1	0.8	0.4	0.5
Coho salmon					0.3					0.2	0.1
Largemouth bass					0.1					0.1	0.0+
Total fish	702	575	1,088	1,147	2,584	140	1,325	1,351	3,512	5,400	
Stations Sampled	22	20	19	24	27	7	20	24	85	78	163
Predominant net length	350'	600'	600'	600'	350'	250'	125'	350'			
Fish per net	31.9	28.8	57.3	47.8	95.7	20.0	66.3	56.3	41.3	69.2	54.7

Table 18. SIZE AND WEIGHT OF FISH SPECIES COLLECTED FROM FLATHEAD LAKE, OCTOBER 1966 THROUGH DECEMBER 1970

	Size Range (T.L.) Minimum		Maximum		Weight		Number of Fish
	in.	(mm)	in.	(mm)	lbs.	(g)	
Dolly Varden	6.6	(168)	36.0	(914)	18.50	(8,391)	985
Lake whitefish	5.5	(140)	23.9	(606)	4.92	(2,233)	2,446
Pygmy whitefish	3.1	(79)	7.2	(183)	0.10	(45)	551
Mountain whitefish	5.3	(135)	17.2	(437)	1.27	(576)	349
Lake trout	7.8	(198)	42.0	(1,067)	32.00	(14,515)	106
Cutthroat trout	8.5	(216)	20.2	(513)	3.30	(1,497)	70
Peamouth	4.7	(119)	13.3	(338)	0.79	(357)	1,439
Northern squawfish	3.4	(86)	22.3	(567)	4.50	(2,128)	1,200
Longnose sucker	4.5	(114)	18.2	(462)	2.09	(948)	178
Largescale sucker	6.4	(163)	25.6	(650)	3.52	(1,597)	104
Yellow perch	5.2	(133)	15.4	(391)	1.01	(496)	702
							8,130

the surface to 90 feet with the majority occurring in waters less than 60 feet deep.

Survivors of the latest introduction of an exotic fish species was the coho salmon made in the lake during the spring of 1969. They were observed in the lake for 18 months and then completely disappeared. Returns of considerably less than one-half percent of the 240,000 smolt-sized salmon were reported. Early growth rates were excellent but slowed after eight months and then dropped off rapidly. Total lengths during the first eight months increased to a maximum of 229 mm (9.0 inches). The largest and last coho recorded as a "jack" salmon measuring 328 mm (12.9 inches) and 348 g (0.77 pounds) on November 3, 1970.

The future of the Flathead Lake fishery is dependent on the natural reproduction produced in the waters of this complex system. The quality of the fishery available will be dependent on the quality of the aquatic habitat. Changes caused by natural variations to this environment, as well as the result of man's activities in water development projects, housing projects, or a combination of all factors will be reflected in the fish populations of this water drainage. The maintenance of a quality sport fishery will be dependent upon the maintenance and preservation of a high quality aquatic habitat in the lake-river system.

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SECTION XV

APPENDIX -- ALGAE OF FLATHEAD LAKE

I. CHLOROPHYTA

A. Volvocales

1. Volvocaceae

Eudorina elegans Ehr.

Gonium pectorale Mueller

Pandorina morum Bory

Volvox aureus Ehr.
Volvox globator

B. Tetrasporales

1. Gloeocystaceae

Asterococcus superbus (Cienk.) Scherf.

Gloeocystis ampla (Kuetz.) Lag.
Gloeocystis gigas (Kuetz.) Lag.
Gloeocystis major Gerneck

2. Tetrasporaceae

Schizochlamys compacta Presc.

Tetraspora gelatinosa (Vauch.) Desv.
Tetraspora lacustris Lemm.

C. Chlorococcales

1. Chlorococcaceae

Characium ambiguum Hermann
Characium acuminatum A. Braun

Chlorococcum humicola (Naeg.) Rab. (?)

Planktosphaeria gelatinosa G.M. Smith

Schroederia Judayi G.M. Smith

Chlorophyta (continued)

2. Coccomyxaceae

Elakatothrix gelatinosa Wille

Dispora crucigenioides Printz

3. Coelastraceae

Coelastrum cambricum Archer

4. Dictyosphaeriaceae

Botryococcus Braunii Kuetz.

Dictyosphaerium pulchellum Wood

5. Hydrodictyaceae

Euastropsis Richteri (Schm.) Lag.

Pediastrum Boryanum (Turp.) Menegh
Pediastrum duplex Meyen
Pediastrum simplex Meyen
Pediastrum sculptatum G.M. Smith
Pediastrum tetras (Ehr.) Ralfs

Sorastrum spinulosum Naeg.

6. Oocystaceae

Ankistrodesmus Braunii (Naeg.) Collins
Ankistrodesmus falcatus (Corda) Ralfs

Cerasterias staurastroides West and West

Chlorella vulgaris Beij.

Closteridium lunula Reinsch

Dactylococcus infusionum Naeg.

Kirchneriella lunaris (Kirch.) Moebius
Kirchneriella obesa (W. West) Schmidle

Mycanthococcus antarcticus Wille

Nephrocytium Agardhianum Naeg.
Nephrocytium limneticum (G.M. Smith) G.M. Smith

Chlorophyta (continued)
Oocystaceae (continued)

Oocystis Borgei Snow
Oocystis crassa Wittr.
Oocystis elliptica W. West
Oocystis lacustris Chodat
Oocystis panduriformis var. minor G.M. Smith
Oocystis solitaria Wittr.
Oocystis submarina Lag.

Quadrigula Chodatii (Tan.-Ful.) G.M. Smith

Selenastrum gracile Reinsch

Tetraedron arthrodesmiforme (G.S. West) Wolsz.
Tetraedron regulare Kuetz.

Trochiscia reticularis (Reinsch) Hansg.

7. Palmellaceae

Sphaerocystis Schroeteri Chodat

8. Scenedesmaceae

Crucigenia rectangularis (Naeg.) Gay

Scenedesmus armatus (Chodat) G.M. Smith
Scenedesmus bijuga (Turp.) Lag.
Scenedesmus quadricauda (Turp.) Breg.

Tetrastrum heteracanthum (Nordst.) Chodat

D. Ulotrichales

1. Microsporaceae

Microspora pachyderma (Wille) Lag.
Microspora stagnorum (Kuetz.) Lag.

2. Ulotrichaceae

Binuclearia tatrana Wittrock

Geminella mutabilis (Bréb.) Wille

Radiofilum conjunctivum Schmidle

Ulothrix zonata (Web. and Moh.) Kuetz.

Chlorophyta (continued)

E. Ulvales

1. Schizogoniaceae

Schizogonium murale Kuetz.

F. Chaetophorales

1. Aphanochaetaceae

Aphanochaeta repens A. Braun

2. Chaetophoraceae

Chaetophora sp.

Microthamnion Kuetzingianum Naeg.

Stigeoclonium tenue (C. Ag.) Kuetz.

3. Coleochaetaceae

Coleochaete scutata de Bréb.

G. Cylindrocapsales

1. Cylindrocapsaceae

Cylindrocapsa geminella Wolle

H. Oedogoniales

1. Oedogoniaceae

Oedogonium spp.

Bulbochaete sp.

I. Conjugales

1. Desmidiaceae

Arthrodesmus incus Anderss.

Bambusina brebissonii Kuetz.

Closterium moniliferum (Bory) Ehr
(as Cl. moniliforme by Morgan)

Chlorophyta (continued)
Desmidiaceae (continued)

Cosmarium protractum (Naeg.) DeBary
Cosmarium punctulatum (Nordst.) Boerges.

Desmidium Grevillii Kuetz.

Docidium undulatum Bailey

Euastrum pectinatum var. inevolutum West and West

Hyalotheca dissiliens (Smith) De Bréb.

Micrasterias americana (Ehr.) Ralfs

Pleurotaenium trabecula (Ehr.) Naeg.

Sphaerozosma vertebratum (Bréb.) Ralfs

Spondylosium moniliforme Lund.
Spondylosium planum (Wolle) West and West

Staurastrum leptocladum Nordst.

Xanthidium subhastiferum W. West

2. Gonatozygaceae

Gonatozygon aculeata Hast.

3. Zygnemataceae

Mougeotia genuflexa (Dillw.) Ag.

Sirogonium sticticum (Engl. Bot.) Kuetz.

Spirogyra communis (Hass.) Kuetz.
Spirogyra gratiana Trans.

Zygnema pectinatum (Fritsch) Stevens

J. Charales

1. Characeae

Chara fragilis Desv.
Chara vulgaris L.

II. CYANOPHYTA

A. Chroococcales

1. Chroococcaceae

Aphanocapsa biformis A. Braun
(A. rivularis)
Aphanocapsa elachista West & West
Aphanocapsa Grevillei (Hass.) Rab.
Aphanocapsa pulchra (Kuetz.) Rab.

Aphanothece nidulans P. Richt.

Chroococcus dispersus (v. Keussl.) Lemm.
Chroococcus giganteus W. West
Chroococcus limneticus Lemm.
Chroococcus minor (Kuetz.) Naeg.
Chroococcus Prescottii Drouet & Daily
Chroococcus turgidus (Kuetz.) Naeg.

Coelosphaerium Naegelianum Unger

Dactylococcopsis acicularis Lemm.

Eucapsis alpinum Clements & Shantz

Gloeocapsa linearis var. composita G.M. Smith
Gloeocapsa punctata Naeg.

Gomphosphaeria aponina Kuetz.
Gomphosphaeria lacustris Chodat

Merismopedia elegans A. Braun
Merismopedia glauca (Ehr.) Naeg.

B. Chamaesiphonales

1. Chamaesiphonaceae

Chamaesiphon incrustans Grunow

C. Oscillatoriales

1. Oscillatoriaceae

Oscillatoria limosa Ag.

Spirulina laxa G.M. Smith

Cyanophyta (continued)

D. Nostocales

1. Nostocaceae

Anabaena circinalis Rab.
Anabaena flos-aquae (Lyngb.) Bréb.

Aphanizomenon flos-aquae (L.) Ralfs

Cylindrospermum muscicola Kuetz.

Nodularia spumigena Mertens

Nostoc linckia (Roth) Bor. & Flah.

2. Scytonemataceae

Tolypothrix lanata Wartm.

3. Rivulariaceae

Gloeotrichia echinulata (J. E. Smith) P. Richter
Gloeotrichia pisum Thuret

Rivularia compacta (?)
Rivularia haematites (D.C.) C. Ag.

III. CHRYSOPHYTA

A. Chrysophyceae

1. Mallomonadaceae

Mallomonas alpina Pascher & Ruttner
Mallomonas caudata Iwanoff
Mallomonas elliptica (Kiss.) Conrad
Mallomonas pseudocoronata Presc.

2. Ochromonadaceae

Dinobryon bavaricum Imhof.
Dinobryon divergens Bachm.
Dinobryon sertularia Ehr.
Dinobryon sociale Ehr.
Dinobryon stipitatum Stein

3. Synuraceae

Synura Adamsii G.M. Smith

Chrysophyta (continued)
Synuraceae (continued)

Synura ulvella Ehr.

B. Xanthophyceae

1. Chlorotheciaceae

Ophiocytium parvulum (Perty) A. Braun

2. Pleurochloridaceae

Arachnochloris minor Pascher

Tetragoniella gigas Pascher

3. Rhizochrysidaceae

Rhizochrysis limnetica G.M. Smith

4. Meringosphaeraceae

Meringosphaera spinosa Presc.

C. Bacillariophyceae

Centrales

1. Coscinodiscaceae

Coscinodiscus bodanica Schneider
Coscinodiscus catenata Brun.
(Coscinodiscus comta (Ehr.) Kuetz.) ?
Coscinodiscus marginatus Ehr.

Cyclotella antigua W. Smith
Cyclotella bodanica En. & Sch.
Cyclotella catenata Brun.
Cyclotella comta (Ehr.) Kuetz.
Cyclotella Kuetzingiana Thw.
Cyclotella Kuetzingiana var. planetophora Fricke
Cyclotella Kuetzingiana var. radiosa Fricke
Cyclotella Kuetzingiana var. Schumannii Grun.
Cyclotella Meneghiniana Kuetz.
Cyclotella ocellata Pant.
Cyclotella operculata (Ag.) Kuetz.
Cyclotella stelligera Cleve & Grun.

Melosira ambigua
Melosira Binderiana Kuetz.

Chrysophyta (continued)
Centrales - Coscinodiscaceae (continued)

Melosira crenulata (Ehr.) Kuetz.
Melosira distans (Ehr.) Ralfs
Melosira granulata (Ehr.) Ralfs
Melosira italica Kuetz.
Melosira italica var. valida Grun.
Melosira italica var. subarctica Müll.
Melosira varians Ag.

Stephanodiscus astraea (Ehr.) Grun.
Stephanodiscus astraea var. minutula (Kuetz.) Grun.
Stephanodiscus Hantzschii Grun.
Stephanodiscus niagarae Ehr.

Pennales

1. Achnanthaceae

Achnanthes affinis Grun.
Achnanthes brevipes Cleve
Achnanthes calcar Cleve
Achnanthes chilensis var. subaequalis Reim.
Achnanthes Clevei Grun.
Achnanthes Clevei var. rostrata Hust.
Achnanthes deflexa Reim.
Achnanthes exiguua Grun.
Achnanthes exiguua var. constricta (Grun.) Hust.
Achnanthes exiguua var. heterovalva Krass.
Achnanthes flexella (Kuetz.) Grun.
Achnanthes inflata (Kuetz.) Grun.
Achnanthes lanceolata (Bréb.) Grun.
Achnanthes lanceolata var. dubia Grun.
Achnanthes lanceolata var. elliptica Cleve
Achnanthes lanceolata var. rhomboides A. Mayer
Achnanthes lapponica var. ninckei (Grun.) Mang.
Achnanthes Lemmermannii Hust.
Achnanthes Levanderi Hust.
Achnanthes linearis f. curta H.L. Smith
Achnanthes macrocephala (Kuetz.) Grun.
Achnanthes minutissima Kuetz.
Achnanthes pergalli Brun. & Herib.
Achnanthes saxonica Krass.
Achnanthes Stewartii Ptr.
Achnanthes sublaevis var. crass Reim.

Cocconeis diminuta Pant.
Cocconeis placentula Ehr.
Cocconeis placentula var. euglypta (Ehr.) Cleve
Cocconeis placentula var. lineata (Ehr.) V.H.

Chrysophyta (continued)
Pennales - Achnanthaceae (continued)

Cocconeis scutellum Ehr.
Cocconeis scutellum f. parva Grun.

Rhoicosphenia curvata (Kuetz.) Grun.

2. Cymbellaceae

Amphora bullatoides Hohn & Heller.
Amphora coffeaeformis (Ag.) Kuetz.
Amphora lineolata (Ehr.) Ehr.
Amphora ovalis (Kuetz.) Kuetz.
Amphora ovalis var. pediculus (Kuetz.) V.H.
Amphora veneta Kuetz.

Cymbella affine Kuetz.
Cymbella aphicephala Naeg.
Cymbella angustata (W. Smith) Cleve
Cymbella aspera (Ehr.) Herib.
Cymbella Brehmii Hust.
Cymbella Cesatii Grun.
Cymbella cistula Grun.
Cymbella cuspidata Kuetz.
Cymbella delicatula Kuetz.
Cymbella delicatula var. intermedia McCall.
Cymbella fluminea Patr.
Cymbella gracilis (Rab.) Cleve
Cymbella heteropleura (Ehr.) Kuetz.
Cymbella Hustedtii Krass.
Cymbella hybrida Grun.
Cymbella laevis Naeg.
Cymbella lata Grun.
Cymbella mexicana (Ehr.) A.S.
Cymbella microcephala Grun.
Cymbella Mulleri var. javanica (Hust.) Hust.
Cymbella naviculiformis (Auer. & Rab.) Kirch.
Cymbella parva (W. Sm.) Cleve
Cymbella perpusilla Cleve
Cymbella pusilla Grun.
Cymbella Reinhatdtii Grun.
Cymbella rhomboidea Boyer
Cymbella similis Patr.
Cymbella sinuata Greg.
Cymbella triangulum (Ehr.) Cleve
Cymbella tumida (Bréb.) V.H.
Cymbella tumidula Grun.
Cymbella turgida Greg.
Cymbella turgidula Grun.
Cymbella ventricosa Ag.

Chrysophyta (continued)
Pennales - Cymbellaceae (continued)

Cymbella ventricosa var. Girodii (Her.) H. Kob.
Cymbella ventricosa var. ovata f. minor Cleve
Cymbella ventricosa var. silesiaca (Bleish) Cleve

Epithemia argus (Ehr.) Kuetz.
Epithemia Reichelti Fricke
Epithemia sorex Kuetz.
Epithemia turgida (Ehr.) Kuetz.
Epithemia turgida var. granulata (Ehr.) Brun.
Epithemia zebra (Ehr.) Kuetz.

Rhopalodia gibba (Ehr.) Müll.
Rhopalodia parallela (Grun.) Müll.

3. Diatomaceae

Diatoma anceps (Ehr.) Kirch.
Diatoma hiemale var. mesadon (Ehr.) Grun.
Diatoma tenue Agardh.
Diatoma tenue var. elongatum Lynbg.
Diatoma vulgare var. pachycephala Grun.
Diatoma vulgare Bory
Diatoma vulgare var. breve Grun.
Diatoma vulgare var. linearis V.H.

Opephora americana M. Perag.
Opephora ansata Hohn & Heller
Opephora Martyi Herib.
Opephora Schwartzii (Grun.) Petit

4. Eunotiaceae

Ceratoneis arcus (Ehr.) Kuetz.
(Eunotia arcus Ehr.)

Eunotia arcus Ehr.
Eunotia arcus var. bidens Grun.
Eunotia curvata Kuetz.
Eunotia pectinalis (Kuetz.) Rab.
= E. pectinalis (O.F. Mull.) Rab.
Eunotia pectinalis var. stricta (Rab.) V.H.
Eunotia praerupta Ehr.
Eunotia Vanheurckii Patr.

5. Fragilariaceae

Asterionella formosa Hass.
Asterionella gracillima (Hantzsch) Heib.

Chrysophyta (continued)
Pennales - Fragilariaceae (continued)

Ceratoneis arcus (Ehr.) Kuetz.
(Fragilaria arcus)

Fragilaria brevistriata Grun.
Fragilaria capucina Desmar.
Fragilaria capucina Desmar. var. mesolepta Rab.
Fragilaria construens (Ehr.) Grun.
Fragilaria construens var. binodis (Ehr.) Grun.
Fragilaria construens var. venter (Ehr.) Grun.
Fragilaria crotonensis Kitton
Fragilaria crotonensis var. oregona Sov.
Fragilaria inflata
Fragilaria intermedia Grun.
(Fragilaria tenuicollis Heib. var. intermedia Grun.)
Fragilaria leptostauron (Ehr.) Hust.
Fragilaria mutabilis var. intercedens Grun.
Fragilaria pinnata Ehr.
Fragilaria pinnata var. intercedens W. Smith
Fragilaria pinnata var. lancettula (Schm.) Hust.
Fragilaria vaucheriae (Kuetz.) Peter.
Fragilaria vaucheriae var. capitellata (Rab.) Patri.

Hannaea arcus (Ehr.) Patr.
Hannaea arcus var. amphioxys (Rab.) Patr.

Synedra actinastroides Lemm.
Synedra acus Kuetz.
Synedra amphicephala var. austrica (Grun.) Hust.
Synedra cyclopum Brutschy
Synedra cyclopum var. gibbosa Mag.
Synedra cyclopum var. robustum Schulze
Synedra delicatissima W. Sm.
Synedra delicatissima var. angustissima Grun.
Synedra Demerarae Grun.
Synedra familica Kuetz.
Synedra fasciculata Kuetz.
Synedra fasciculata var. truncata (Grev.) Patr.
Synedra incisa Boyer
Synedra mazamaenses Sov.
Synedra parasitica (W. Smith) Hust.
Synedra parasitica var. subconstricta (Grun.) Hust.
Synedra pulchella Ralfs ex Kuetz.
Synedra radians (Kuetz.) Grun.
Synedra rumpens var. fragilarioides Grun.
Synedra rumpens var. scotica Grun.
Synedra ulna (Nitzsch) Ehr.
Synedra ulna var. amphirhynchus (Ehr.) Grun.
Synedra ulna var. danica (Kuetz.) V.H.
Synedra ulna var. spathulifera (Grun.) V.H.

Chrysophyta (continued)
Pennales (continued)

6. Gomphonemataceae

Didymosphenia geminata (Lyngb.) M. Schmidt

Gomphoneis acuminata var. Brebissonii
(Gomphonema acuminata var. Brebissonii (Kuetz.) Grun.)

Gomphonema acuminata var. coronata (Ehr.) Rab.
Gomphonema acuminatum var. Brebissonii (Kuetz.) Grun.
Gomphonema angustatum var. obesa Lauby
Gomphonema constrictum var. capitatum (Ehr.) V.H.
Gomphonema geminatum (Lyngb.) Kuetz.
Gomphonema gracile var. aurita (A.Br.) Cleve
Gomphonema intricatum Kuetz.
Gomphonema intricatum var. bohemicum (Rech. & Tr.)
Gomphonema intricatum var. dichotomum (Kuetz.) Grun.
Gomphonema intricatum var. pumila Grun.
Gomphonema longicepsf. gracilis Hust.
Gomphonema olivaceioides Hust.
Gomphonema olivaceum (Lynbg.) Kuetz.
Gomphonema parvulum (Kuetz.) Kuetz.
Gomphonema parvulum var. micropus (Kuetz.) Cleve
Gomphonema septata Magh.

7. Meridionaceae

Meridion circulare (Grev.) Ag.
Meridion circulare var. constrictum (Ralfs) V.H.

8. Naviculaceae

Amphipleura Lindheimeri Grun.
Amphipleura pellucida Kuetz.

Amphiprora ornata Bailey

Anomoeoneis sphaerophora (Kuetz) Pfitzer
Anomoeoneis sphaerophora var. sculpta O. Hull.
Anomoeoneis vitrea (Grun.) Ross
Anomoeoneis vitrea f. lanceolata (A. Mayer) Mogh.
Anomoeoneis vitrea var. gomphonemacea (Grun.) Mogh.

Caloneis amphisbaena (Bory) Cleve
Caloneis bacillum (Grun.) Cleve
Caloneis lewisii var. inflata (Schultz) Patr.
Caloneis silicula f. Foged.
Caloneis ventricosa (Ehr.) Meist.
Caloneis zachariasii Reich.

Chrysophyta (continued)
Pennales - Naviculaceae (continued)

Diploneis elliptica (Kuetz.) Cleve
Diploneis oculata (Bréb.) Cleve
Diploneis oculata var. linearis Gallik.
Diploneis ostracodarum (Pant.) Jur.

Frustulia rhomboides var. amphipleuroides (Grun.) Cleve
Frustulia vulgaris (Thw.) DeToni
Frustulia vulgaris var. capitata Krass.

Gyrosigma acuminatum (Kuetz.) Cleve
Gyrosigma attenuatum var. hippocampus (W.Sm.) Brock
Gyrosigma exilis (Grun.) Reimer
Gyrosigma eximium (Thw.) Boyer
Gyrosigma Kuetzingii (Grun.) Cleve
Gyrosigma obtusatum (Sulliv. & Worm.) Cleve
Gyrosigma sciotense (Sulliv. & Worm.) Cleve
Gyrosigma Spenceri (Quek.) G. & H.

Mastogloia Braunii Grun.
Mastogloia Grevillei W. Sm.
Mastogloia Smithii Thw.
Mastogloia Smithii var. amphicephala Grun.
Mastogloia Smithii var. lacustris Grun.

Navicula absoluta Hust.
Navicula amphibela Cleve
Navicula anglica var. subsalsa (Grun.) Cleve
Navicula arenaria Donk.
Navicula aurora Sov.
Navicula bacillum Ehr.
Navicula bicapitellata Hust.
Navicula capitata var. hungarica (Grun.) Ross
Navicula capitata var. luneburgensis (Grun.) Patr.
Navicula cocconeiformis Greg.
Navicula costulata Grun.
Navicula cryptocephala Kuetz.
Navicula decussin Ostr.
Navicula disjuncta Hust.
Navicula eligensis (Greg.) Ralfs
Navicula flavasinus Mogh.
Navicula gastrum (Ehr.) Kuetz.
Navicula Gaufinii Mogh.
Navicula graciloides A. Mayer
Navicula gregaria Donk
Navicula Harderi Hust.
Navicula Heufleri var. leptocephala Bréb.
Navicula ingrata Krass.
Navicula Jaernefeltii Hust.

Chrysophyta (continued)
Pennales - Naviculaceae (continued)

Navicula laevissima Kuetz.
Navicula lanceolata (Ag.) Kuetz.
Navicula latens Krass.
Navicula laterostrate Hust.
Navicula Lundstromii Cleve
Navicula menisculus var. upsaliensis (Grun.) Grun.
Navicula minima Grun.
Navicula minuscula Grun.
Navicula montana Mogh.
Navicula muralis Grun.
Navicula peregrina (Ehr.) Kuetz.
Navicula peticolasii M. Perag.
Navicula pseudoreinhardtii Patr.
Navicula pseudoscutiformis Hust.
Navicula pupula Kuetz.
Navicula pupula var. capitata Shv. & Mey.
Navicula pupula var. elliptica Hust.
Navicula pupula var. rectangularis (Greg.) Grun.
Navicula pusio Cleve
Navicula pygmea Kuetz.
Navicula radiosa Kuetz.
Navicula radiosa var. parva Wallace
Navicula radiosa var. tenella Bréb.
Navicula rhyncocephala var. amphiceros (Kuetz.) Grun.
Navicula rotunda Hust.
Navicula salinarum Grun.
Navicula scutelloides W. Smith
Navicula secura Patr.
Navicula seminulum Grun.
Navicula simula Patr.
Navicula subhamulata Grun.
Navicula subocculata Hust.
Navicula subscutelloides
Navicula subtillisima Cleve
Navicula Swaniana Mogh.
Navicula tantula Hust.
Navicula tripunctata var. schizonemoides (V.H.) Patr.
Navicula tuscula Ehr.
Navicula tuscula f. minor
Navicula Utermohleii Hust.
Navicula variostriata Krass.
Navicula viridula (Kuetz.) Kuetz.
Navicula viridula var. avenacea (Bréb.) V.H.
Navicula viridula var. linearis Hust.
Navicula vitabunda var. montana Mogh.
Navicula vulpina Kuetz.

Neidium affine (Ehr.) Pfitz.

Chrysophyta (continued)
Pennales - Naviculaceae (continued)

Neidium affine var. amphirhynchus (Ehr.) Cleve
Neidium affine var. ceylonicum (Skv.) Cleve
Neidium binodis Hust.
Neidium dubium (Ehr.) Cleve
Neidium hercynicum f. subrostratum Wallace
Neidium iridis var. amphigomphus (Ehr.) A. Mayer
Neidium iridis var. ampliatum (Ehr.) Cleve
Neidium koslowi Meresch.
Neidium magellanicum Cleve
Neidium temperi Reimer

Pinnularia abaujensis var. linearis (Hust.) Patr.
Pinnularia abaujensis var. subundulata A. Mayer
Pinnularia biceps Greg.
Pinnularia biceps f. Petersenii Ross
Pinnularia borealis Ehr.
Pinnularia borealis var. rectangularis Caris.
Pinnularia Brebissonii (Kuetz.) Rab.
Pinnularia gibba (Ehr.) Hust.
Pinnularia Hilseana Jan.
Pinnularia major (Kuetz.) Rab.
Pinnularia Martyi (?)
Pinnularia mesogonglya Ehr.
Pinnularia mesolepta (Ehr.) Sm.
Pinnularia microstauron (Ehr.) Cleve

Pleurosigma delicatulum W. Sm.

9. Nitzschiaceae

Bacillaria paradoxa Gmel.

Hantzschia amphioxys (Ehr.) Grun.

Nitzschia acicularis (Kuetz.) W. Sm.
Nitzschia acuta Hantz.
Nitzschia amphibia Grun.
Nitzschia angustata (W.Sm.) Grun.
Nitzschia angustata var. acuta Grun.
Nitzschia bacata Hust.
Nitzschia bremensis Hust.
Nitzschia capitellata Hust.
Nitzschia congolensis Hust.
Nitzschia denticula Grun.
Nitzschia dissipata (Kuetz.) Grun.
Nitzschia filiformis (W.Sm.) Schutt
Nitzschia fonticola Grun.
Nitzschia frustulum var. subsalina Hust.

Chrysophyta (continued)
Pennales - Nitzschiaceae (continued)

Nitzschia Hantzschiana Rab.
Nitzschia Kuetzingianum Hilse
Nitzschia linearis (W.Sm.) W. Smith
Nitzschia microcephala Grun.
Nitzschia parvula Lewis
Nitzschia palea (Kuetz.) W. Sm.
Nitzschia recta Hantz.
Nitzschia sinuata (W. Sm.) Grun. var. tabellaria V.H.
Nitzschia vermicularis (Kuetz.) Hantz.

10. Rhizosoleniaceae

Rhizosolenia eriensis H. L. Smith
Rhizosolenia eriensis var. morsa West & West
Rhizosolenia stagnalis

11. Surirellaceae

Campylodiscus hibernicus Ehr.

Cymatopleura solea (Bréb.) W. Smith
Cymatopleura solea var. apiculata (W.Smith) Ralfs

Surirella angustata Kuetz.
Surirella biseriata var. bifron (Ehr.) Hust.
Surirella capronii Bréb.
Surirella didyma Kuetz.
Surirella linearis W. Smith
Surirella linearis var. helvetica (Brun.) Meister
Surirella oblonga Ehr.
Surirella ovalis Bréb.
Surirella ovata Kuetz.
Surirella robusta Ehr.
Surirella tenera Greg.

12. Tabellariaceae

Tabellaria fenestrata Kuetz.
Tabellaria flocculosa (Roth) Kuetz.
Tabellaria quadrisepta Knuds.

Tetracyclus lacustris Ralfs